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U.S. COMPUTER RESEARCH NETWORKS:

CURRENT AND FUTURE

EXECUTIVE SUMMARY

PREPARED FOR:

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PREFACE

This document presents a summary of the report which was prepared by Contel Federal Systems for the NASA Lewis Research Center under Task Order 2 of the Contract NAS3-25083. Under this contract, Contel Federal Systems provides technical support to NASA for the assessment of the future market for satellite communications services. Task Order 1 focused on the costs and tariffs for telecommunications services. Task Order 2, the results of which are summarized in this Executive Summary, focused on the current and future telecommunications requirements of the United States research community.

ACKNOWLEDGEMENTS

The authors would like to thank members of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), members of the Federal Research Internet Coordinating Committee (FRICC), and other Federal agency representatives who provided information on their networks. Special thanks are due to EDUCOM representatives, directors and managers of the various computer research networks, and the staff of the Corporation for National Research Initiatives for their cooperation. These individuals and other government, industry and academic leaders provided much needed information and valuable insights for this study.

Special thanks are due also to the NASA Lewis Research Center and the technical officer of this study, Mr. James E. Hollansworth, for providing direction and guidance for this study.

SUMMARY

During the last decade, the Government Networks Division of Contel Federal Systems has assisted NASA in conducting a series of telecommunications forecasting studies to project trends and requirements, and to identify critical telecommunications technologies that must be developed to meet future requirements. The current study builds upon earlier efforts, and estimates the U.S.'s current and future needs for research and development (R&D) telecommunications networks.

NASA is concerned that the future telecommunications capacity requirements of the U.S. R&D community are not being factored in the national level planning of communications resources. There are two problems. One, will there be adequate capacity to meet the projected requirements of the U.S. R&D community in the years 2000 or 2010? Given the long gap between conception and implementation, it is imperative that the requirements be assessed now and the means to satisfy the requirements be identified now. Two, what are the cost savings associated with implementation of an integrated research network (IRN) compared with several interconnected networks, owned and operated by a number of entities, as is the case today. This study projects the capacity requirements, and shows that substantial cost savings can be realized by implementing an integrated network, rather than several smaller interconnected networks.

Four major tasks were performed to develop estimates of communications requirements of the U.S. R&D community. First, federal agencies' current research communications networks were identified, defined and described. Second, an integrated research network (IRN) designed to meet the combined current requirements of all research networks was sized. Third, given this definition of the Current IRN and the results of an analysis of projected events and trends, Future IRNs (i.e., for 1991, 1996, 2000 & 2010) designed to meet the combined future requirements of all research networks were sized. Fourth, based on these definitions of Current and Future IRNs, the costs of the Current and Future IRNs were estimated.

It should be noted that this study is limited to domestic requirements. It does not factor in additional capacity requirements generated by ever-increasing international cooperative resarch efforts. Also, for the purpose of this study, a network's installed capacity was used as a measure of its traffic. Estimates of traffic loads or of peak hour traffic were not available for most of the networks included in this study.

The major networks selected for this study were, by agency: DoD (Advanced Research Agency Proejcts Network-ARPANET, Defense Research Internet); NSF (NSFNET---Backbone, 21 mid-level and over 250 campus networks); NASA (NASA Science Network, Space Physics Analysis Network, Numerical Aerodynamics Simulation Network, NASA Communications); DOE (Energy Science Network, Magnetic Fusion Energy Network, High Energy Physics Network, LEP3NET, OPMODEL); Other (BITNET, CSNET).

The Current (1989) IRN was estimated to have 40 major access points and a T1 backbone with 187 T1 links. In 1991, the major access points and connectivity were projected to be the same, but much of the 1991 IRN backbone was projected to have T3 capacity. In 1996, ten new major access points were added, and link capacities were increased as follows: some 1991 T3 links were increased to 1 gigabits per second (Gbps) links; some 1991 T3 links were increased to 564/274 megabits per second (Mbps) links; all 1991 T1 links were increased to 564/274 Mbps links; and all new access points were connected by either 90 or 45 Mbps links.

In 2000, major access points and connectivity were projected to be the same as for 1996, but link capacities were increased as follows: all 1996 1 Gbps links were increased to 5 Gbps links; all 1996 564/274 Mbps links were increased to 1 Gbps links; and all 1996 90/45 Mbps links were increased to 564/274 Mbps links. Similarly, in 2010, major access points and connectivity were projected to be the same as for 2000, but link capacities were increased as follows: all 2000 5 Gbps links were increased to 25 Gbps links; all 2000 1 Gbps links were increased to 5 Gbps links; and all 2000 564/274 Mbps links were increased to 1 Gbps links.

While the IRN capacity was projected to increase by about a factor of 1800, from 1989 to 2010, monthly circuit costs of the IRN were projected to increase by only about a factor of 20. The implications of not fully integrating the IRN in 1996 and beyond were found to be significant. In 1996, the monthly cost of an IRN that is not fully integrated was projected to be about double the cost of a fully integrated IRN. In 2000, it was projected to be about triple the cost. In 1996, the fully integrated IRN monthly circuit costs were estimated to be about five million dollars less than the non-fully integrated IRN costs. This difference increases to about sixty million dollars per month in 2010. Exhibit ES-25 on page ES-55 presents a summary of the IRN cost projections.

Major findings of this study are summarized in Section 3 of this report. A more comprehensive report which includes data on major networks is also available.

RECOMMENDATIONS

A consensus of academic, industry, and institutional experts engaged in developing and operating computer research networks is that significantly higher communications capacities will be needed in the years to come to link researchers to enable them to collaborate in cooperative research endeavors regardless of their physical locations. The researchers' needs for communications will encompass accessing large data bases, linking supercomputers in a massively paralleled configuration, and presenting simulation results with ever-increasing resolution and clarity to permit researcher to overcome resource limitations. From that perspective, communications could be viewed as enhancing the effectiveness of research facilities in the same manner as command, control and communications are viewed as force multipliers by the defense community.

NASA needs to address several technology and policy issues in order to translate today's vision into what some experts have called the "Collaboratory" of the future. Some specific recommendations are as follows:

1. Broaden the scope of the current study to include the communications requirements of ever-increasing international

cooperation among researchers.

2. Participate in standards setting committees to actively set the standards for door-to-door delivery of data at rates approaching gigabits and terabits per second.

3. Examine the current and future capacity plans of the commercial communications industry vis-a-vis researchers' needs, and identify communications assets such as satellites or terrestrial systems that are needed to meet researchers' unique requirements.

4. Identify technologies in the areas of computer networking, communications systems, and communications networks management that need to be developed to meet researchers' requirements in the year 1996 and beyond.

5. Identify policy issues that must be resolved to provide communications facilities to researchers in a most cost effective manner. The current approach of implementing several interconnected networks does not take advantage of economies of scale and does not place responsibility on a single organization to integrate requirements into a national level initiative.

SECTION 1

STUDY OVERVIEW AND BACKGROUND

1.1 STUDY OVERVIEW

During the last decade, the NASA Lewis Research Center's Communications Program has conducted a series of telecommunications forecasting studies to project communications trends and requirements, and to identify critical telecommunications technologies that must be developed to meet future requirements. The Government Networks Division of Contel Federal Systems has assisted NASA in these studies, and the current study builds upon these earlier efforts.

1.2 STUDY BACKGROUND

The current major thrust of the NASA Comunications Program is aimed at developing the high risk, advanced communications satellite and terminal technologies required to significantly increase the capacity of future communications systems. Also, major new technological, economic, and social-political events and trends are now shaping the communications industry of the future.

Therefore, a re-examination of future telecommunications needs and requirements is necessary to enable NASA to make management decisions in its Communications Program and to ensure that proper technologies and systems are addressed. This re-examination is being accomplished through a series of studies which are helping NASA define the likely communication service needs and requirements of the future, and thereby, ensuring that the most appropriate technology developments are pursued.

Previous studies have dealt with the costs and tariffs for telecommunications services. The current study, the results of which are summarized in this volume, focused on telecommunications requirements for the U.S. research and development community.

SECTION 2

METHODOLOGY

2.1 PURPOSE

The purpose of this study was to assist NASA in determining the U.S.'s current and future needs for research and development telecommunications networks. This understanding of network needs is helping NASA define the future technology requirements and thereby ensuring that the most appropriate technology developments are pursued.

2.2 TASKS

This study accomplished its purpose of determining current and future research communications needs by undertaking the following tasks:

1. Identifying, defining and describing federal agencies' current research communications networks;
2. Sizing an integrated research network to meet the combined current requirements of all research networks;
3. Sizing an integrated research network to meet the combined future requirements of all research networks;
4. Estimating the costs of the current and future integrated research network.

2.3 APPROACH

To accomplish the purpose of this study, the study approach depicted in Exhibit ES-1 was used. This study approach will be summarized for each of the four major tasks listed above.

2.3.1 Identifying, Describing And Defining Networks

To identify, define and describe current computer research networks,

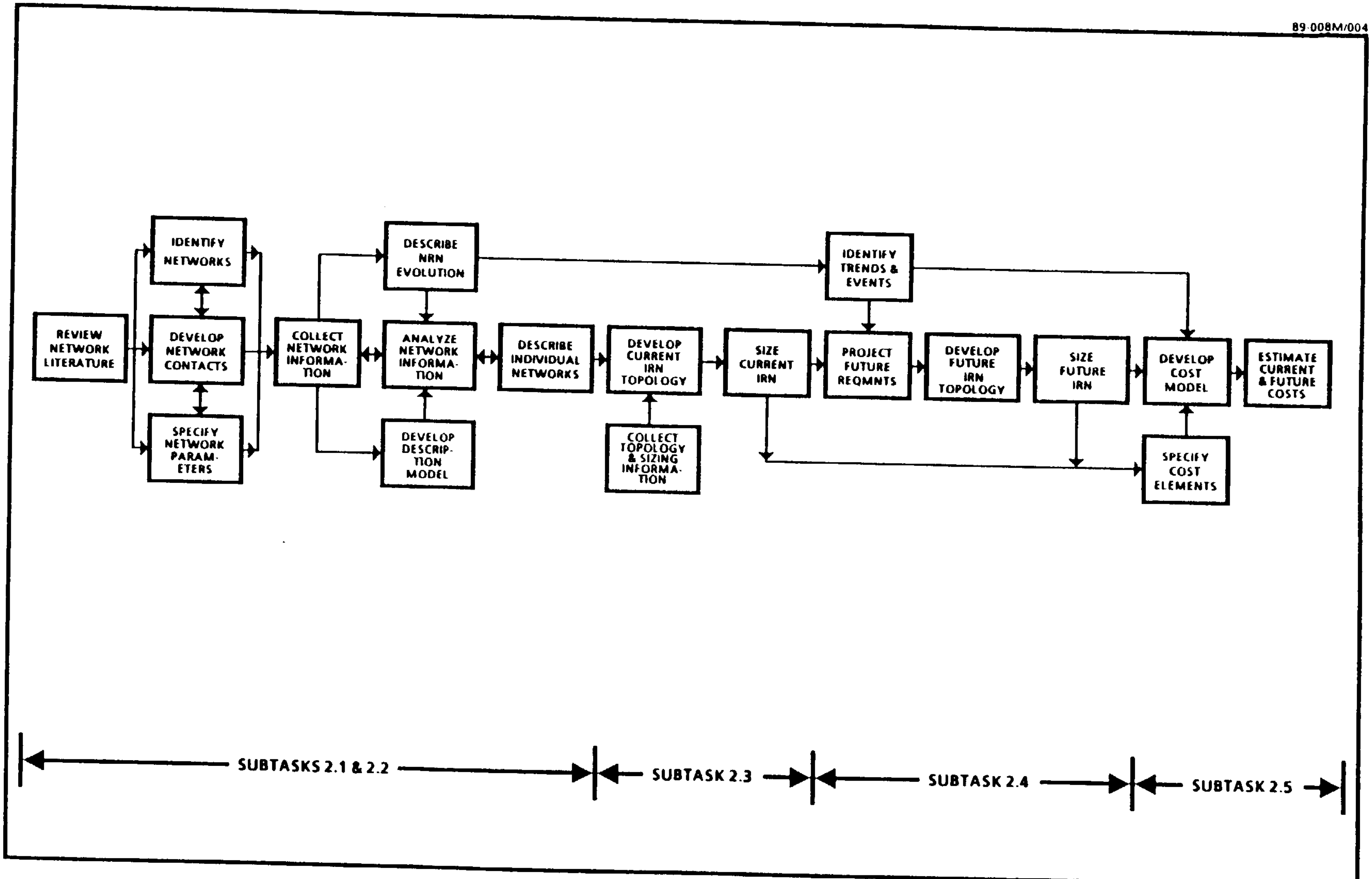

EXHIBIT ES-1. STUDY APPROACH

a computer research network was defined, a model for describing such a network was developed, the evolution of a national research network was described, and networks were selected and described.

The following is the definition, developed for this study, of a computer research network. A computer network exists when independent computers are connected in some way that allows them to exchange information. For the purposes of this study, when such a network is used by scientists for scientific research purposes, it is designated as a computer research network. In a computer network, the computers can range in size from small microcomputers to supercomputers. These computers can be connected by a variety of media, such as optical fiber, microwave, copper, and/or satellites. The common conventions or rules that define how these computers communicate with each other are the communication protocols. Therefore, for the purpose of this study, a computer research network was defined as a communications network connecting a set of computers used by scientific researchers to exchange scientific data over a variety of communications media using common conventions or protocols.

Based on the definition presented above, a model for describing computer research networks (CRNs) was developed. This CRN model is outlined in Exhibit ES-2. The model includes descriptions of the following computer network topics: history; types; extent and size; computers, nodes and topologies; media; speed, throughput, and bandwidth; layers and protocols; services; uses; administration; and the future. The CRN model was used to describe the networks that were selected for comprehensive review.

An extensive amount of effort has been, and continues to be, devoted to the development of a conceptual National Research Network (NRN). The results of this effort were used to design and conduct the current study. Likewise, it is expected that the results of the current study will be helpful in the future planning of the NRN. To better understand this relationship between the current study and the development of an NRN, a summary of the activities underlying the development of an NRN and the organizations responsible for the NRN concept was developed.

EXHIBIT ES-2. MODEL FOR DESCRIBING NETWORKS

HISTORY

WHEN STARTED, IMPETUS, MAJOR CHANGES

TYPE OF NETWORK

NETWORK, INTERNET, METANETWORK

PURPOSES & SERVICES

WHY IT WAS DEVELOPED AND FOR WHOM, SERVICES OFFERED

EXTENT & SIZE

GEOGRAPHICAL COVERAGE, #NODES/HOSTS

TOPOLOGY

PICTURE - LOCATION & CONNECTIVITY OF NODES

COMPUTERS

PURPOSE AND SIZE OF COMPUTERS

MEDIA & LINK SPEEDS

TYPE OF MEDIA, SPEEDS IN BITS PER SECOND (BPS)

PROTOCOLS

NAME OF PROTOCOL SUITE (E.G., TCP/IP)

ADMINISTRATION

WHO - POLICY, OPERATION, INFORMATION

FUNDING

WHO PROVIDED SUPPORT

FUTURE

PLANS - TECHNOLOGICAL, POLITICAL

To identify the major computer research networks sponsored by the federal government, all major federal agencies were contacted. First, an initial list of federal agencies of interest was developed, and this list was reviewed to determine which agencies were most likely to have computer research networking requirements and/or interests. Based on this review, a second list was developed of agencies expected to have such requirements and/or interests. This list, which is presented in Exhibit ES-3, includes those agencies which were actually contacted.

Information on these federal agencies' networks was collected through telephone interviews, personal interviews and analysis of existing publications and reports. For each of the agencies contacted, the following information was collected: name, address, telephone number of agency contact person; and type of networks the agency uses (i.e., those managed by and/or funded by them and those that they merely access). Based on the information obtained from the federal agencies, a brief summary of the computer networks sponsored by and/or used by these agencies was developed. This information then was reviewed and analyzed. The majority of the agencies contacted have or use telecommunications networks for operational and administrative purposes. Most of these agencies do not have their own computer research network, but they usually have access to such networks when they need them.

Based on the review and analysis described above and on the information obtained when examining the evolution of the NRN, a perspective on scientific research and computer research networks was developed. This perspective is depicted in Exhibits ES-4 and ES-5. In Exhibit ES-4, research is divided into "activities on ground" and "activities in space," and in both instances, the activities can be either national or international. A single scientific research effort may involve any of the possible combinations of research activities, i.e., on ground, in space, national or international. The current effort has focused primarily on national (i.e., the United States) research activities on the ground and in space.

The types of United States computer research networks examined in this study are listed in Exhibit ES-5 and include various types of

EXHIBIT ES-3. FEDERAL AGENCIES CONTACTED

- Agriculture, Dept. of
- Commerce, Dept. of
  - National Institute of Standards & Technology (NIST)
  - National Telecommunications & Information Administration (NTIA)
  - National Oceanic & Atmospheric Administration (NOAA)
- Defense, Dept. of
  - Defense Advanced Research Projects Agency (DARPA)
  - Defense Communications Agency (DCA)
- Education, Dept. of
- Energy, Dept. of
- Environmental Protection Agency (EPA)
- Health & Human Services, Dept of
  - National Institutes of Health
  - National Library of Medicine
- Housing and Urban Development, Dept. of
- Interior, Dept. of
  - U.S. Geological Survey
  - Bureau of Mines
  - Office of Surface Mining Reclamation
  - Fish & Wildlife Service
  - Minerals Management Service
- Justice, Dept. of
- Library of Congress
- National Academy of Sciences
- National Aeronautics & Space Administration
- National Science Foundation
- Nuclear Regulatory Commission
- Transportation, Dept. of
  - U.S. Coast Guard
  - Federal Aviation Administration
- Treasury, Dept. of the
- Veteran's Administration

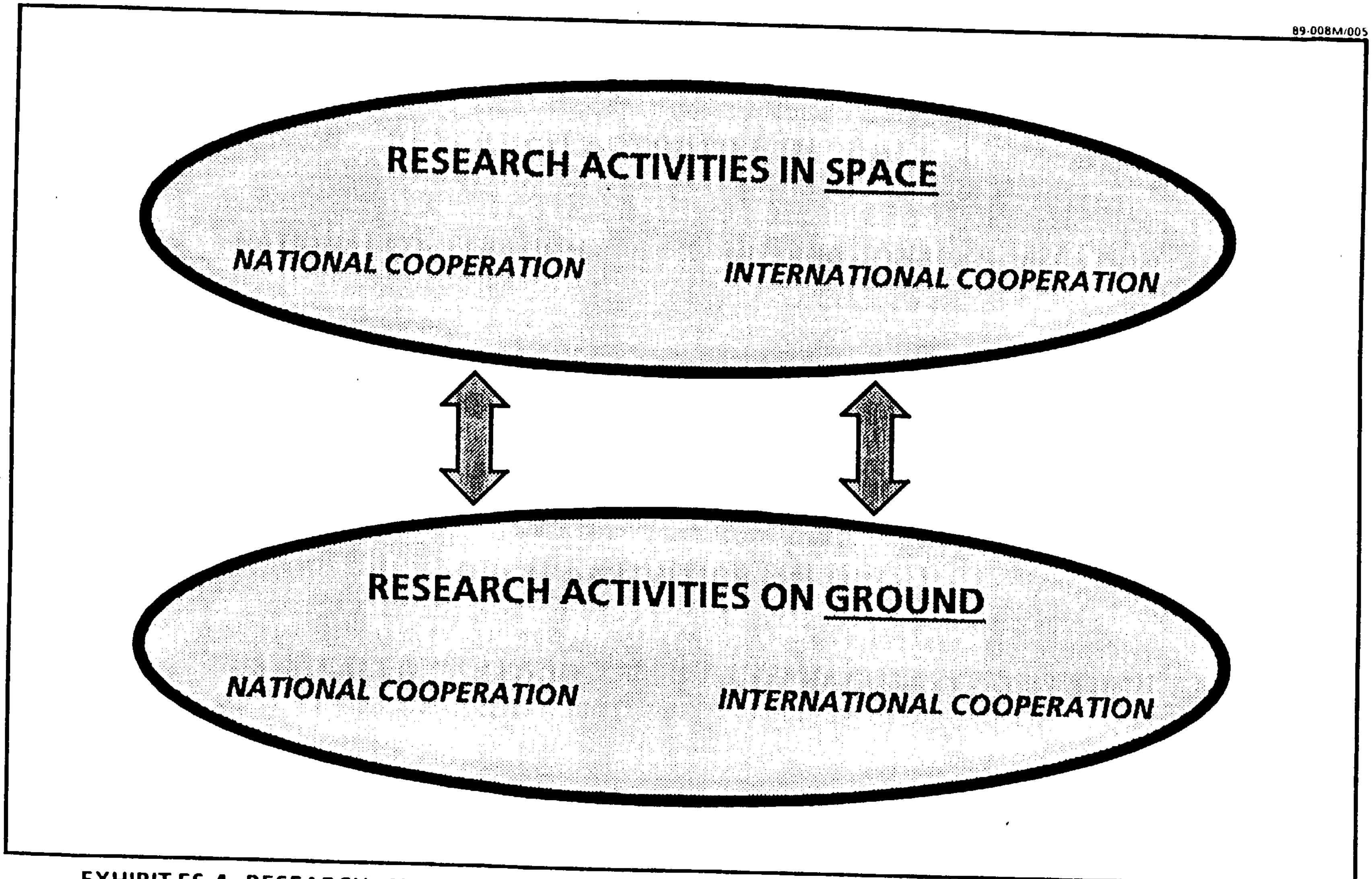

EXHIBIT ES-4. RESEARCH - NATIONAL AND INTERNATIONAL COOPERATION ON GROUND AND IN SPACE

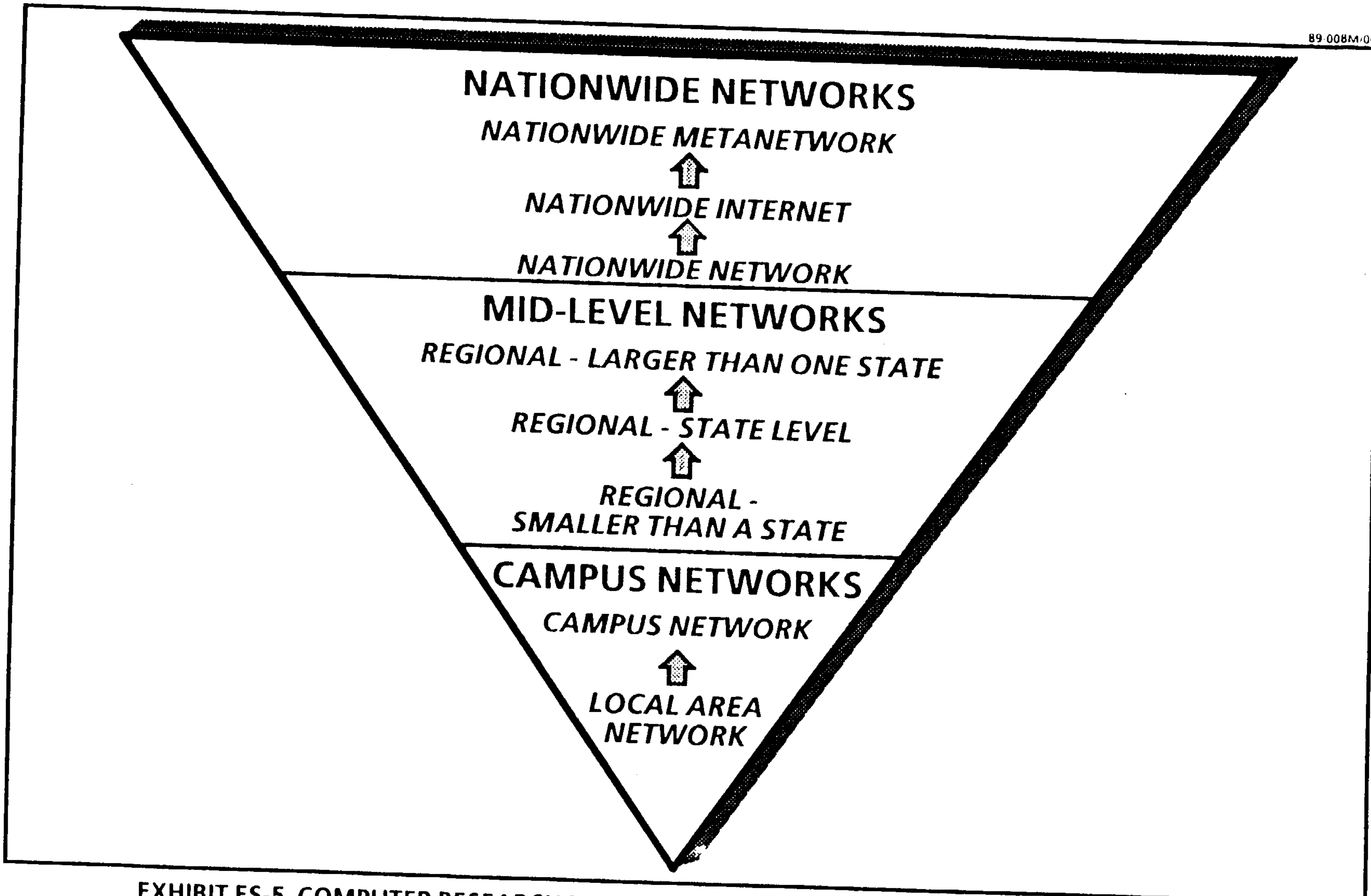

EXHIBIT ES-5. COMPUTER RESEARCH NETWORKS FOR U.S. RESEARCH ACTIVITIES ON GROUND nationwide, mid-level and campus area networks. An inverted triangle is used to depict the various sizes of networks and the relationship of smaller networks to larger ones. The adjectives "smaller" and "larger" are used here to denote geographical areas rather than capacities.

Based on the perspective described above, the results of the analysis of federal agencies' network use, and the information obtained when describing the evolution of the NRN, the networks selected for comprehensive examination in this study were identified. Then each of these networks were described using the CRN model presented in Exhibit ES-2. To develop these descriptions additional information was collected on each network through interviews and the review of network literature.

2.3.2 Sizing The Current Integrated Research Network

The comprehensive descriptions of the selected computer research networks then were used to develop the topology of an integrated research network (IRN) representing the aggregation of selected major current computer research networks, and to size the Current IRN.

The major activities conducted to size the Current IRN included: collecting current topology data, developing a network database, identifying major access points, determining major access point connectivity, determining the link capacity between major access points, and defining the Current IRN.

After the current topology information was collected and organized, a main network database was developed so that the network information could be analyzed when sizing the Current IRN. This database then was used to identify major access points. Common hubs and common routes were identified by noting where the various networks overlapped. Once these major access points were selected, their connectivity was determined by reorganizing the original main network database in terms of these major access points.

The database then was used to note how many links originated from each major access point, what their terminations were and what their speeds were. This information then was used to specify the IRN backbone and the capacity requirements of the various segments of the backbone. The Current IRN then was defined in terms of this IRN backbone and link capacity.

2.3.3 Sizing The Future Integrated Research Network

Given the definition of the Current IRN, information on events and trends expected to impact future development of the IRN was collected and analyzed. Then the definition of the current IRN and the results of this analysis of events and trends were used to develop projections of the size of the IRN at future points in time.

The major activities conducted to size the Current IRN included: reviewing th literature on projections related to an IRN, identifying relevent events and trends, surveying experts in the field, analyzing results of the literature review and survey, specifying benchmark years, identifying new major access points, developing a future IRN database, projecting backbone link speeds and defining IRN for each benchmark year.

Previously collected literature (e.g., national reports, journal articles, and conference summaries) were reviewed to identify strategies for projecting, and actual projections of, the future requirements for an IRN. The results of this review suggested that a combination of qualitative and quantitative factors should be considered when projecting the future requirements for an IRN.

These qualitative and quantitative factors involved:

1. Network Needs And Usage - i.e., the future needs of scientists, usage growth trends, and the addition of new groups of users.
2. Network Development - i.e., the development of new networks and the reconfiguration of existing networks.
3. Federal Government Activity - e.g., legislation and funding support.
4. Private Telecommunications Company Activity - e.g., financial support and research and development participation.
5. NRN Plans - e.g., FRICC, FCCSET and EDUCOM projections,
6. Technological Changes - e.g., advances related to developing a Gbps

network.

7. Economic Pressures - e.g., international competition motivating both federal and private support for an IRN.

These factors were used to develop a brief guide for surveying leaders in the field of computer research networks. Some fifteen experts were asked to give their opinions, and the basis for them, of when and how a national computer research network might develop in the future. Then, the survey information and the initial literature review findings were analyzed, and the results of the anlysis were used to identify appropriate benchmark years, identify additional major access points, and project link speeds for the future IRNs.

Based on the analysis noted above the following guidelines were specified for projecting the future IRN:

1. Benchmark years would be: 1989 (Current), 1991, 1996, 2000, and 2010.
2. Major access points would be the same for 1989 and 1991; new major access points would be added in 1996 and traffic centers in 2000 and 2010 would be the same as for 1996.
3. For the sake of clarity, only the IRN backbone would be depicted for each benchmark year; while many non-major access points will be added yearly, these would not be presented in the projections.
4. Connectivity would be the same for 1989 and 1991; it also would be the same for 1996, 2000 and 2010 with new access points added for 1996.
5. The IRN link speeds would include DS1 (T1), DS3 (T3), DS4(T4), and Gbps speeds; several speeds would be used for each benchmark year; and the magnitude of speed increases would reflect technology/use projections.

Given these guidelines, the current network database was used to develop a new future network database, reflecting the changes in major access points, connectivity and link speeds, for each of the four future benchmark years. These databases then were used to develop the definitions of the IRN for four benchmark years.

2.3.4 Estimating Current And Future IRN Circuit Costs

Once the definitions of the current and future nationwide integrated computer research networks were developed, it was possible to estimate the current and future circuit costs of the IRN. The definitions of the IRN, along with current and future cost models and databases, were used to estimate circuit costs for each of the benchmark years.

The major activities conducted to size the Current IRN included: converting area code and exchange information to V & H coordinates; developing averaging costs per mile for various T1 links; developing a cost model for Current IRN costing; estimating circuit costs of the Current IRN; developing the 1991 IRN database; estimating the 1991 IRN circuit costs; developing a cost model for 1996, 2000 and 2010 IRN; and estimating circuit costs of the IRN for 1996, 2000 and 2010.

First, the approach used to estimate circuit costs for the various benchmark years was developed. The approach used to estimate Current IRN costs and the 1991 IRN costs was different from that used to estimate IRN costs for 1996, 2000 and 2010. The major reason for using different approaches is that it was assumed that in 1989 and 1991 the IRN would not be integrated from a cost point of view, but would be in 1996 and beyond. In 1989 and 1991 the trunking requirements for each of the selected networks were costed individually. For each of the benchmark years, 1996, 2000 and 2010, the trunking requirements of the total IRN were costed.

The first step in estimating Current IRN circuit costs was to determine the V (vertical) and H (horizontal) coordinates of each major access point. The V and H coordinates then were used to determine the mileage between any two of the access points. Next, a sample of the major access point area codes and exchanges were used to obtain real tariff data from the Network Analysis Center in Great Neck, New York for 56 Kbps and T1 services. This sample of real tariff data was used to develop the average circuit cost per mile for various link distances. It should be emphasized that these costs pertain to circuit costs and do not include costs associated with the end user interface equipment.

Given the mileage between any two access points on the Current IRN and the average cost per mile for various 56 Kbps and T1 links, a Current IRN cost database was developed. This cost database reflected the Current

IRN definition and included the Current IRN cost model that was based on current tariff costs and IRN link distances. The database then was used to calculate the current costs of each link on the IRN and the total cost for the entire Current IRN.

To estimate the circuit cost of the 1991 IRN, the Current IRN cost database and cost model were modified to reflect the 1991 IRN definition and the costs of T3 links. To estimate the costs of T3 links, it was assumed that carriers would cost future circuit offerings as they had in the past. That is, the increase in cost, for example, from a DS0 (64 Kbps) to a DS1 (1.544 Mbps), was used to estimate the increase in cost from DS1 to a DS3. The increase in cost from a DS0 to a DS1 which offers 24 times the capacity of a DS0 has been about a factor of six. Therefore, the ratio of capacity increase to cost increase is about four (i.e., 24/6 = 4). That is: New Cost = (Capacity Increase/4) X Lower Speed Cost. Therefore, the increase in cost from a T1 to a T3 which offers 28 times the capacity of a T1 would be about a factor of seven. Or, T3 Cost = (28/4) X T1 Cost. As calculated for the Current 1989 IRN, the estimated circuit costs of each network in the 1991 IRN and the total cost for the entire 1991 IRN were calculated.

To estimate the future IRN circuit costs for 1996, 2000 and 2010, new cost models and new cost databases were developed. For the new cost models, costs of higher speed links were estimated in the same manner as noted above for estimating the cost of T3 links from T1 link costs. Given these estimates of higher speed links, an IRN cost model was developed for each of the benchmark years of 1996, 2000 and 2010. An IRN cost database then was developed for each of these benchmark years using the definitions of the IRNs developed for each of these years and the estimated future circuit costs of the various link speeds and distances. Then, these cost databases were used to estimate the future IRN costs for 1996, 2000, and 2010.

SECTION 3

MAJOR FINDINGS

3.1 OVERVIEW

The major findings of this study are summarized below and focus on: the evolution of a national research network; the descriptions of the selected United States computer research networks; the Current IRN; the Future IRN; and estimates of current and future IRN circuit costs.

3.2 EVOLUTION OF A NATIONAL RESEARCH NETWORK (NRN)

The evolution of an NRN is diagrammed in Exhibit ES-6. The history of the NRN summarized in this exhibit covers the period of 1984 through the Spring of 1989 and focuses on the interrelationships between four groups of events: the development of major research networks; the pursuit of related legislative agenda; the formation of national-level committees and offices; and the performance of key national studies.

The results of this examination of the evolution of an NRN suggest that a number of key questions concerning an NRN remain to be answered. The key questions that remain to answered are listed below.

<u>Key Questions</u>

1. What do we mean by <u>research</u>? Is it limited to a miniscule scientific community engaged in advancing frontiers of science, or does it include supporting engineering and development types of activities. While some have broadened research to include all of education, others expect an NRN to be more limited, especially in the near-term, in its application.

2. Who should <u>use</u> the network? Potential users range from the scientific researcher to the general public.

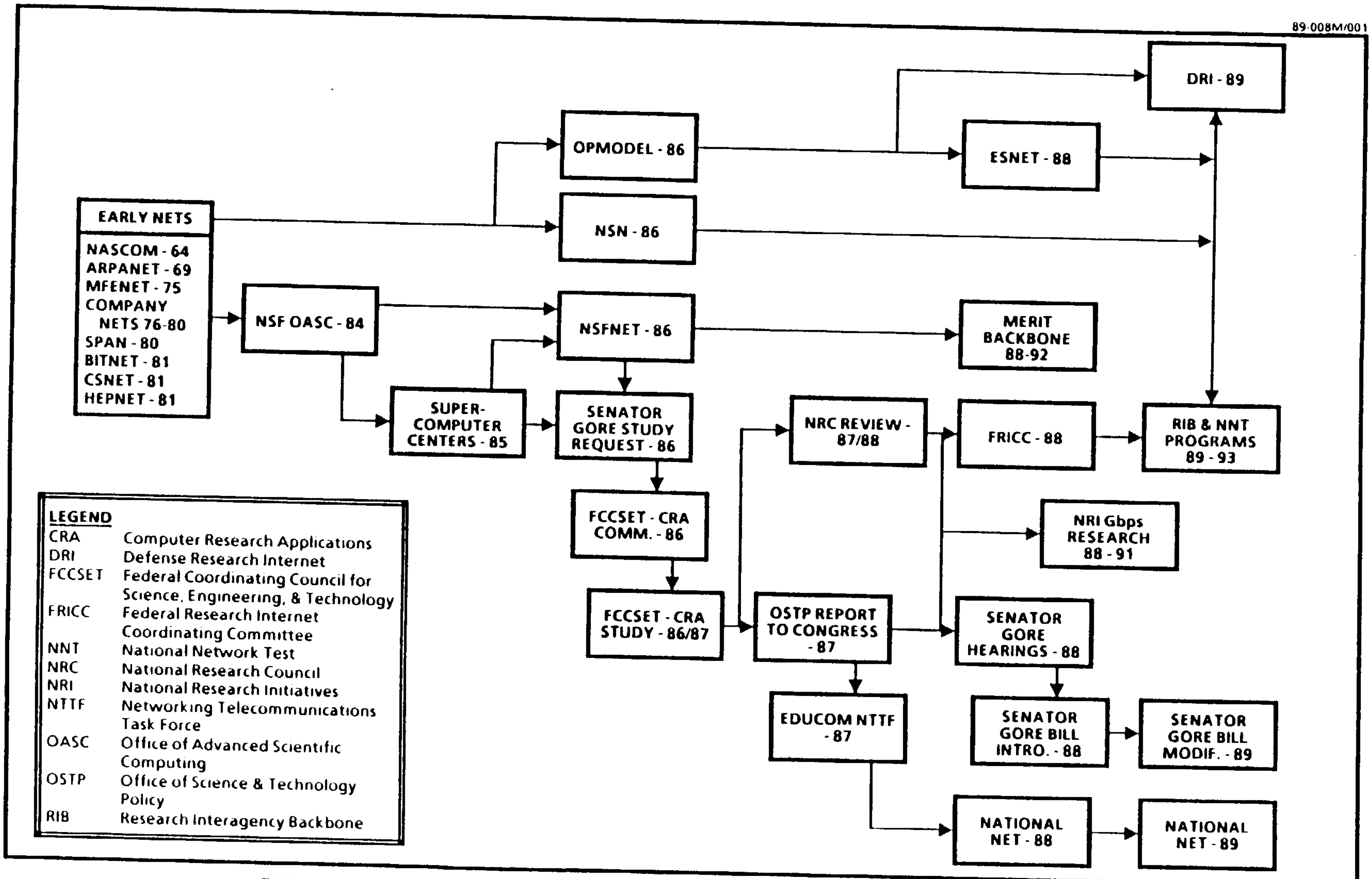

EXHIBIT ES-6. EVOLUTION OF A NATIONAL RESEARCH NETWORK (84-89)

3. Who should <u>manage</u> the network? Government? Academia? Not-for-profit organizations? Business/Industry? Or, some combination of these groups?

4. Who should <u>pay</u> for the network creation and operation? Suggestions range from treating the NRN as a government investment to a utility. Suggestions also have been made for basing payment on the stage of network development and on the user and usage.

5. What are the network <u>needs</u> and <u>requirements</u>? Will we really need to send giga bits per second (Gbps) traffic door-to-door, and if so, what requirements will this impose on the backbone network? If we need to send 1 Gbps door-to-door, will we need a backbone that supports data rates on the order of 10 to 100 Gbps?

6. How do we <u>transition</u> from where we are to where we need to be? What research and development steps must be taken? How do we ensure that all stakeholders are represented? What institutional changes are necessary?

7. What are the <u>international</u> implications? What are the implications of the sharing of ideas and resources on an international scale for our NRN requirements, our security, and our economic competitiveness? Should we work towards linking every scholar in the world with every other scholar?

3.3 DESCRIPTIONS OF SELECTED NETWORKS

Based on the information obtained when describing the evolution of the NRN, the results of the analysis of federal agencies' network use, and the perspective of scientific research and computer research networks, the following networks were selected for comprehensive examination in this study:

1. Department of Defense (DoD) research networks: Advanced Research Projects Agency (ARPANET), Defense Research Internet (DRI).

2. National Science Foundation Network (NSFNET): three level network including a national backbone, twenty-one mid-level networks, and over 250 campus networks.

3. National Aeronautics and Space Administration (NASA) networks: NASA Science Internet (NSI), NASA Science Network (NSN), Space Physics Analysis Network (SPAN), Numerical Aerodynamics Simulation Network (NASNET), and NASA Communications (NASCOM).

4. Department of Energy research networks: Energy Science Network (ESNET), Magnetic Fusion Energy Network (MFENET), High Energy Physics Network (HEPNET), LEP3NET (A Cern accelerator experiment network), and OPMODEL (An advanced satellite network).

5. BITNET (Before Its Time Network) and CSNET (Computer + Science Network). BITNET and CSNET were included because so many researchers and scientist (e.g., those at NIH) use these networks.

These selected networks (also listed in Exhibit ES-7) are national (i.e., United States) networks used for research activities on the ground and in space. As a group they serve researchers across the United States and have worldwide connections. Individually, these networks are in different states of development (i.e., from initial operation to being replaced), and vary, for example, in size, capacity, protocols and services. Each of these networks were comprehensively described using the CRN model presented earlier in Exhibit ES-2. The information on these comprehensively examined networks provided the data base for sizing a current and projecting a future composite integrated computer research network.

3.4 THE CURRENT INTEGRATED RESEARCH NETWORK (IRN)

The major findings obtained from the activities conducted to size the current integrated computer research network are presented in terms of the following: the major access points and their V & H coordinates; the Current IRN links; and the Current IRN topology.

EXHIBIT ES-7. NETWORKS SELECTED

1. Department of Defense (DOD) research networks:
   - Advanced Research Projects Agency Network (ARPANET)
   - Defense Research Internet (DRI)

2. National Science Foundation Network (NSFNET) - Three level network:
   - National backbone
   - Twenty-one mid-level networks
     - Thirteen Original Backbone and Regional Networks:
       - NORTHWESTNET, BARRNET, SDSCNET, WESTNET, USAN, MIDNET, SESQUINET, NCSNET, MERIT, PSCNET, NYSERNET, JVNCNET, SURANET.
     - Eight New Regional Network:
       - CERFNET, CICNET, LOS NETTOS, MRNET, NEARNET, OARNET, PREPNET, THENET.
   - Over 250 campus networks

3. National Aeronautics & Space Administration (NASA) research networks:
   - NASA Science Internet (NSI)
   - NASA Science Network (NSN)
   - Space Physics Analysis Network (SPAN)
   - Numerical Aerodynamics Simulation Network (NASNET)
   - NASA Communications (NASCOM)

4. Department of Energy (DOE) research networks:
   - Energy Science Network (ESNET)
   - Magnetic Fusion Energy Network (MFENET)
   - High Energy Physics Network (HEPNET)
   - LEP3NET (A Cern Accelerator Experiment Network)
   - OPMODEL

5. BITNET (Before Its Time Network) and
   CSNET (Computer + Science Network)

3.4.1 Current IRN Major Access Points

The major access points for the Current IRN are listed with their state and V & H coordinates in Exhibit ES-8. These access points are: Albuquerque, Austin, Boston, Boulder, Chicago, Cleveland, Columbus, Dallas, Detroit, Houston, Huntsville, Indianapolis, Iowa City, Ithaca, Kansas City, Kennedy Space Center, Lincoln, Livermore, Los Angeles, Madison, Miama, Minneapolis, New York, Norfolk, Oak Ridge, Philadelphia, Pittsburgh, Portland, Princeton, Salt Lake City, San Diego, San Francisco, Seattle, Sate College, Tallahassee, Tucson, Urbana, Wallops Island, Washington, and White Sands.

3.4.2 Current IRN Links

The links between pairs of the major access points listed above and the capacity of these links are listed in Exhibit ES-9. For City A and City B the following information is presented: city ID (i.e., major access point name), city name, city state, and link speed (i.e., capacity).

3.4.3 Current IRN Topology

The Current IRN topology, based on these major access point links, is depicted in Exhibits ES-10. Exhibit ES-10 depicts the major access point T1 connectivity in the Current IRN. The numbers for the various links represent the number of T1s required for the various links. A total of 187 T1s were estimated to be required for the Current IRN.

3.5 THE FUTURE INTEGRATED RESEARCH NETWORK (IRN)

The major findings obtained from the activities conducted to size the future integrated computer research network are presented in terms of the IRN city A and city B links and capacities for the future benchmark years and the topology maps showing major access point connectivity for each of the future benchmark years.

KEY	CITY	STATE	V	H
AB	ALBUQUERQUE	NM	8549	5887
AU	AUSTIN	TX	9005	3996
BO	BOSTON	MA	4422	1249
BD	BOULDER	CO	7456	5961
CH	CHICAGO	IL	5986	3426
CL	CLEVELAND	OH	5574	2543
CB	COLUMBUS	OH	5972	2555
DL	DALLAS	TX	8436	4034
DT	DETROIT	MI	5536	2828
HU	HOUSTON	TX	8938	3536
HN	HUNTSVILLE	AL	7267	2535
IN	INDIANAPOLIS	IN	6272	2992
IO	IOWA CITY	IA	6315	3971
IT	ITHACA	NY	4798	1990
KS	KANSAS CITY	MO	7249	4210
KN	KENNEDY SPC CTR	FL	7919	0880
LI	LINCOLN	NE	6823	4674
LL	LIVERMORE	CA	8504	8606
LA	LOS ANGELES	CA	9213	7878
MD	MADISON	WI	5890	3798
MI	MIAMI	FL	8351	0527
MP	MINNEAPOLIS	MN	5781	4525
NY	NEW YORK	NY	4997	1406
NF	NORFOLK	VA	5936	1198
OR	OAK RIDGE	TN	6811	2303
PH	PHILADELPHIA	PA	5251	1458
PT	PITTSBURGH	PA	5621	2185
PO	PORTLAND	OR	6799	8914
PR	PRINCETON	NJ	5120	1436
SL	SALT LAKE	UT	7576	7065
SD	SAN DIEGO	CA	9468	7629
SF	SAN FRANCISCO	CA	8492	8719
SE	SEATTLE	WA	6336	8896
SC	STATE COLLEGE	PA	5360	1933
TL	TALLAHASEE	FL	7876	1715
TU	TUCSON	AZ	9342	6480
IL	URBANA	IL	6371	3336
WI	WALLOPS ISLAND	VA	5657	1249
DC	WASHINGTON	DC	5622	1583
WS	WHITE SANDS	NM	9132	5742

EXHIBIT ES-8. Current IRN Major Access Points

CURRENT IRN TRAFFIC LINKS - SORT CITY - A ID

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	1544
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	1544
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	1544
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT ES-9. Current IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	1544
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT ES-9. Current IRN Links & Capacity

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	1544
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544
PT	PITTSBURGH	PA	IL	URBANA	IL	1544
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT ES-9. Current IRN Links & Capacity

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						146824

EXHIBIT ES-9. Current IRN Links & Capacity

(Continued)

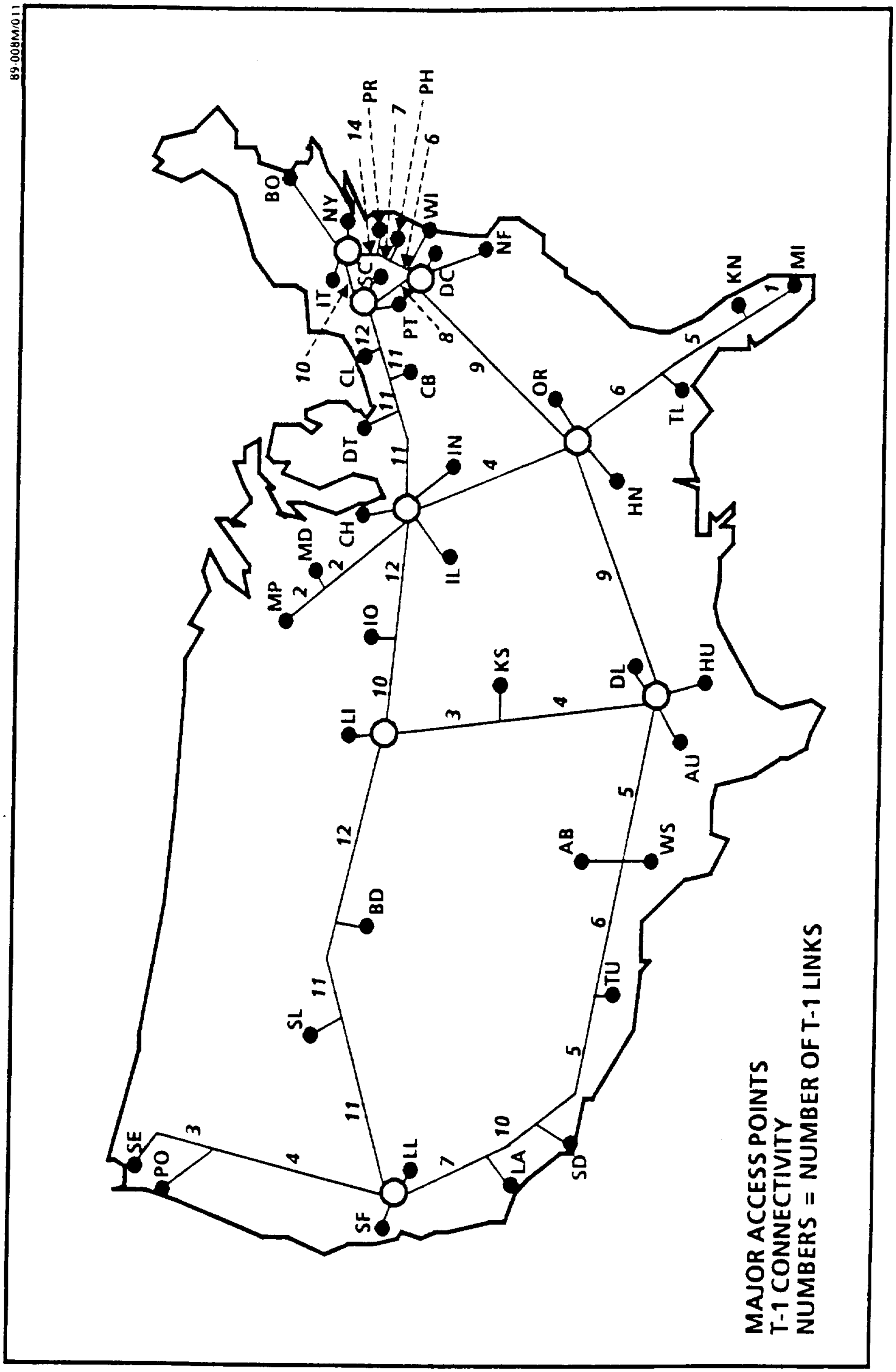

EXHIBIT ES-10. Current IRN Topology

3.5.1 1991 IRN Links And Topology

The 1991 IRN links are listed in Exhibit ES-11. The names of the 1991 links are identical to the Current IRN links that were presented in Exhibit ES-9. Again, the ID (i.e., major access point identification), name and state for City A and for City B and the capacity for each City A/City B link are listed. The major change from the Current IRN to the 1991 IRN was the increase in capacity from T1 to T3 on some links. It was assumed that the NSFNET Backbone capacity would increase from T1 to T3 by 1991, and this expected increase was reflected in the 1991 IRN backbone.

The 1991 IRN Topology is depicted in Exhibit ES-12. The 1991 connectivity has not changed from the Current (i.e., 1989) connectivity, but the capacity of the IRN backbone has. Much of the 1991 IRN backbone is projected to have T3 capacity in 1991.

3.5.2 1996 IRN Links And Topology

For the 1996 IRN, ten new major access points were added, making a total of fifty major access points. These fifty major access points are listed in Exhibit ES-13. The ten new major access points are: Atlanta, Billings, Cheyenne, Columbus, Columbia, Fargo, Helena, Jacksonville, New Orleans, Raleigh and St Louis.

The 1996 IRN links are listed in Exhibit ES-14. As with the Current and 1991 IRN link lists, the ID (i.e., major access point identification), name and state for City A and for City B and the capacity for each City A/City B link are listed. However, even though the number of major access points has increased by ten, the number of links listed has decreased from 177 links in 1991 to 53 links in 1996. This is because only direct links are listed for 1996. For example, in 1996 there are only two links from Seattle (Seattle to Helena and Seattle to San Francisco), while in 1991 there were five. This change in procedure for listing links was made because the 1996 IRN was assumed to be a truly single integrated network, while the 1991 and Current (1989) IRNs were assumed to be composites of many networks with several individual links.

1991 IRN LINKS

ID	CITY - A	ST	ID	CITY	ST	CAPACITY
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544
BD	BOULDER	CO	MD	MADISON	WI	224
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56
BD	BOULDER	CO	DC	WASHINGTON	DC	224
BD	BOULDER	CO	BO	WOODS HOLE	MA	224
BD	BOULDER	CO	MI	MIAMI	FL	224
BD	BOULDER	CO	TU	TUCSON	AZ	56
BD	BOULDER	CO	DT	ANN ARBOR	MI	224
BD	BOULDER	CO	PO	CORVALIS	OR	1544
BD	BOULDER	CO	PO	CORVALLIS	OR	224
BD	DENVER	CO	LA	LOS ANGELES	CA	1544
BO	BOSTON	MA	NY	NEW YORK	NY	1544
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544
CH	CHICAGO	IL	SE	SEATTLE	WA	44M
CH	CHICAGO	IL	DT	LANSING	MI	1544
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56
CH	CHICAGO	IL	MD	MADISON	WI	1544
CH	CHICAGO	IL	BD	DENVER	CO	44M
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56
CH	CHICAGO	IL	IL	URBANA	IL	1544
CH	CHICAGO	IL	LI	LINCOLN	NE	44M
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56
DC	WASHINGTON	DC	LA	BARSTOW	CA	224

EXHIBIT ES-11. 1991 IRN Links & Capacity

DC	WASHINGTON	DC	LA	BARSTOW	CA	56
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56
DC	WASHINGTON	DC	PR	PRINCETON	NJ	44M
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M
DC	WASHINGTON	DC	LA	PASADENA	CA	448
DC	WASHINGTON	DC	LA	PASADENA	CA	280
DC	WASHINGTON	DC	LA	LOMPOC	CA	224
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56
DC	WASHINGTON	DC	NF	NORFOLK	VA	56
DC	WASHINGTON	DC	HU	HOUSTON	TX	56
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280
DC	WASHINGTON	DC	NY	NEW YORK	NY	56
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	44M
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56
HU	BRYAN	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	DL	DALLAS	TX	56
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56
HU	HOUSTON	TX	AU	AUSTIN	TX	1544
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	BD	BOULDER	CO	44M
HU	HOUSTON	TX	AU	AUSTIN	TX	56
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544
IL	URBANA	IL	CH	CHICAGO	IL	1544
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544
IL	URBANA	IL	MD	MILWAUKEE	WI	56
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544
IO	IOWA CITY	IA	IL	URBANA	IL	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	NY	NEW YORK	NY	1544
IT	ITHACA	NY	DC	WASHINGTON	DC	44M
IT	ITHACA	NY	PT	PITTSBURGH	PA	44M
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56

EXHIBIT ES-11. 1991 IRN Links & Capacity

(Contined)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56
LA	LOS ANGELES	CA	BD	BOULDER	CO	56
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544
LA	PASADENA	CA	TU	TUCSON	AZ	56
LA	PASADENA	CA	DC	BALTIMORE	MD	56
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168
LA	PASADENA	CA	DC	WASHINGTON	DC	672
LI	LINCOLN	NE	IL	URBANA	IL	56
LI	LINCOLN	NE	KS	LAWRENCE	KS	56
LI	LINCOLN	NE	IO	IOWA CITY	IA	56
LI	LINCOLN	NE	BD	BOULDER	CO	44M
LL	LIVERMORE	CA	SF	OAKLAND	CA	56
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544
NY	NEW YORK	NY	IT	ROME	NY	1544
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544
PR	PRINCETON	NJ	BD	BOLDER	CO	1544
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544
PR	PRINCETON	NJ	BO	AMHERST	MA	1544
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	44M
PT	PITTSBURGH	PA	IL	URBANA	IL	44M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544
SD	SAN DIEGO	CA	HU	HOUSTON	TX	44M
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	44M
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56

EXHIBIT ES-11. 1991 IRN Links & Capacity

(Contined)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56
SD	SAN DIEGO	CA	LA	IRVINE	CA	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56
SE	SEATTLE	WA	SD	SAN DIEGO	CA	44M
SE	SEATTLE	WA	SF	MENLO PARK	CA	44M
SE	SEATTLE	WA	PO	PORTLAND	OR	56
SE	SEATTLE	WA	PO	CORVALLIS	OR	56
SE	SEATTLE	WA	PO	EUGENE	OR	56
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	44M
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	44M
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	44M
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224
sum						

EXHIBIT ES-11. 1991 IRN Links & Capacity

(Contined)

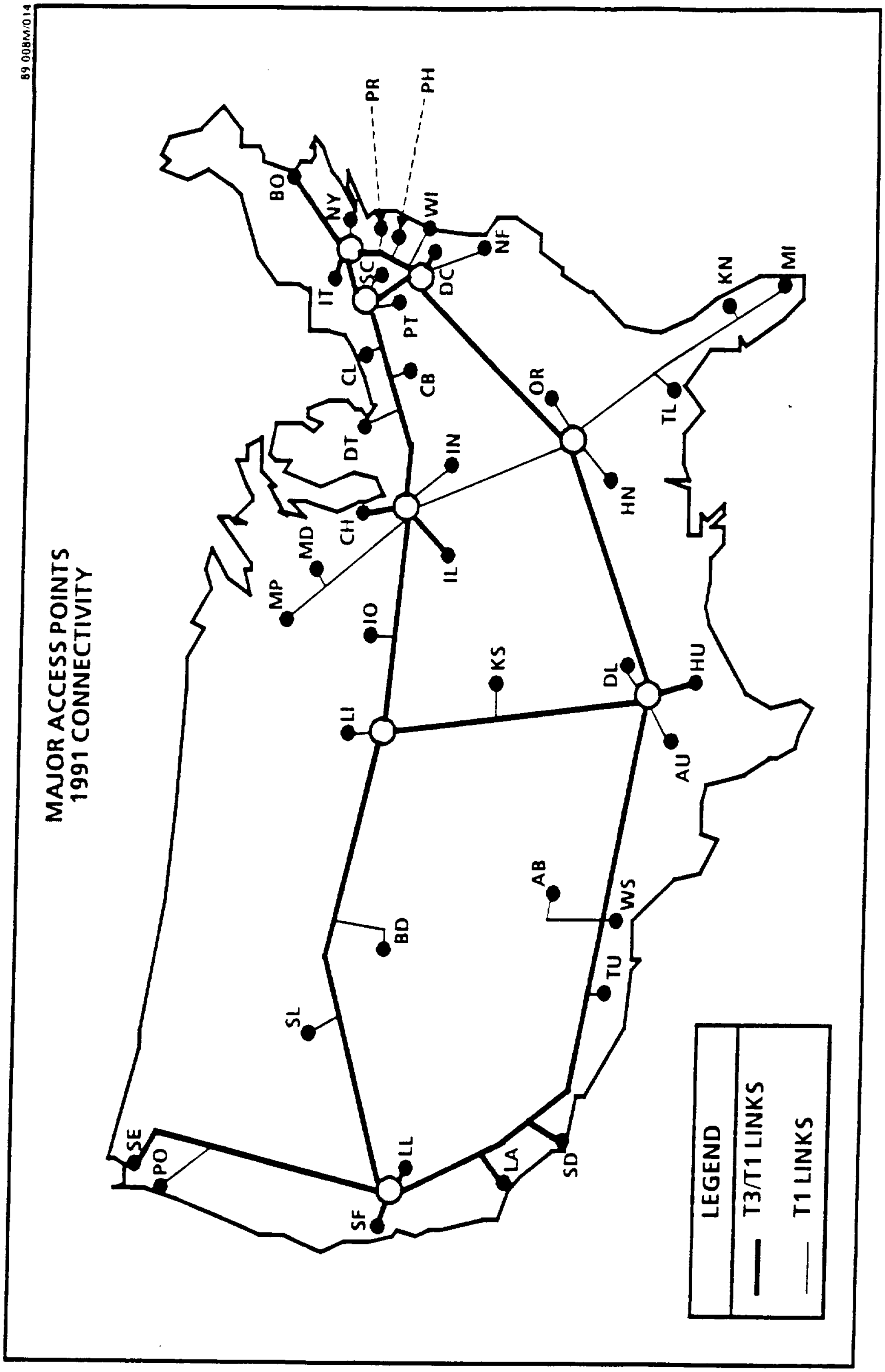

EXHIBIT ES-12. 1991 IRN Topology

KEY	CITY	STATE	V	H
AB	ALBUQUERQUE	NM	8549	5887
AT	ATLANTA	GA	7243	2092
AU	AUSTIN	TX	9005	3996
BI	BILLINGS	MT	6390	6790
BO	BOSTON	MA	4422	1249
BD	BOULDER	CO	7456	5961
CY	CHEYENNE	WY	7204	5958
CH	CHICAGO	IL	5986	3426
CL	CLEVELAND	OH	5574	2543
CO	COLUMBIA	SC	6902	1587
CB	COLUMBUS	OH	5972	2555
DL	DALLAS	TX	8436	4034
DT	DETROIT	MI	5536	2828
FR	FARGO	ND	5614	5181
HE	HELENA	MT	6339	7350
HU	HOUSTON	TX	8938	3536
HN	HUNTSVILLE	AL	7267	2535
IN	INDIANAPOLIS	IN	6272	2992
IO	IOWA CITY	IA	6315	3971
IT	ITHACA	NY	4798	1990
JK	JACKSONVILLE	FL	7642	1276
KS	KANSAS CITY	MO	7249	4210
KN	KENNEDY SPC CTR	FL	7919	0880
LI	LINCOLN	NE	6823	4674
LL	LIVERMORE	CA	8504	8606
LA	LOS ANGELES	CA	9213	7878
MD	MADISON	WI	5890	3798
MI	MIAMI	FL	8351	0527
MP	MINNEAPOLIS	MN	5781	4525
NO	NEW ORLEANS	LA	8484	2631
NY	NEW YORK	NY	4997	1406
NF	NORFOLK	VA	5936	1198
OR	OAK RIDGE	TN	6811	2303
PH	PHILADELPHIA	PA	5251	1458
PT	PITTSBURGH	PA	5621	2185
PO	PORTLAND	OR	6799	8914
PR	PRINCETON	NJ	5120	1436
RL	RALEIGH	NC	6344	1434
SL	SALT LAKE	UT	7576	7065
SD	SAN DIEGO	CA	9468	7629
SF	SAN FRANCISCO	CA	8492	8719
SE	SEATTLE	WA	6336	8896
ST	ST LOUIS	MO	6807	3483
SC	STATE COLLEGE	PA	5360	1933
TL	TALLAHASEE	FL	7876	1715
TU	TUCSON	AZ	9342	6480
IL	URBANA	IL	6371	3336
WI	WALLOPS ISLAND	VA	5657	1249
DC	WASHINGTON	DC	5622	1583
WS	WHITE SANDS	NM	9132	5742

EXHIBIT ES-13. 1996 IRN Major Access Points

1996 IRN LINKS

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	565M
AT	ATLANTA	GA	CO	COLUMBIA	SC	90M
AT	ATLANTA	GA	TL	TALLAHASEE	FL	90M
AU	AUSTIN	TX	DL	DALLAS	TX	90M
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	90M
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	1G
BI	BILLINGS	MT	CY	CHEYENNE	WY	90M
BI	BILLINGS	MT	FR	FARGO	ND	90M
BO	BOSTON	MA	NY	NEW YORK	NY	1G
CB	COLUMBUS	OH	DT	DETROIT	MI	90M
CH	CHICAGO	IL	IL	URBANA	IL	1G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	565M
CH	CHICAGO	IL	LI	LINCOLN	NE	1G
CH	CHICAGO	IL	DT	DETROIT	MI	90M
CH	CHICAGO	IL	ST	ST LOUIS	MO	90M
CL	CLEVELAND	OH	CB	COLUMBUS	OH	90M
CO	COLUMBIA	SC	RL	RALEIGH	NC	90M
CY	CHEYENNE	WY	BD	BOULDER	CO	90M
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1G
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	90M
FR	FARGO	ND	MP	MINNEAPOLIS	MN	90M
HE	HELENA	MT	BI	BILLINGS	MT	90M
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	90M
HU	HOUSTON	TX	OR	OAK RIDGE	TN	565M
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	90M
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	90M
IT	ITHACA	NY	NY	NEW YORK	NY	1G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	90M
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G
LI	LINCOLN	NE	HU	HOUSTON	TX	1G
LI	LINCOLN	NE	BD	BOULDER	CO	1G
LI	LINCOLN	NE	IO	IOWA CITY	IA	90M
MD	MADISON	WI	CH	CHICAGO	IL	565M
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	90M
NY	NEW YORK	NY	DC	WASHINGTON	DC	1G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	1G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	565M
PO	PORTLAND	OR	SE	SEATTLE	WA	90M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	90M
PT	PITTSBURGH	PA	CH	CHICAGO	IL	1G
RL	RALEIGH	NC	NF	NORFOLK	VA	90M
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	90M
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	565M
SE	SEATTLE	WA	HE	HELENA	MT	90M
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	565M
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1G
SL	SALT LAKE	UT	BD	BOULDER	CO	90M
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	90M
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	565M
TU	TUCSON	AZ	WS	WHITE SANDS	NM	90M

EXHIBIT ES-14. 1996 IRN Links & Capacity

The 1996 IRN topology is depicted in Exhibit ES-15. For the 1996 IRN, the 1991 IRN backbone still exists but its capacity has been increased. Also, the ten new major access points have been connected to this 1991 backbone. The following increases in capacity have been made:

1. Some of the 1991 T3 links have been increased to 1 Gbps links.
2. Some of the 1991 T3 links have been increased to 564/274 Mbps links.
3. All 1991 T1 links have been increased to 564/274 Mbps links.
4. The capacity of each of the links added to connect the ten new major access points was either 90 Mbps or 45 Mbps.

3.5.3 2000 IRN Links And Topology

The 2000 IRN links are listed in Exhibit ES-16. The major access points and connectivity for the 2000 IRN are identical to those for the 1996 IRN. The only changes that were made were in the link capacities.

The 2000 IRN topology is depicted in Exhibit ES-17. This topology map looks identical to the topology map for the 1996 IRN. However, the link capacities have been increased in the following manner:

1. All 1996 1 Gbps links have been increased to 5 Gbps links.
2. All 1996 564/274 Mbps links have been increased to 1 Gbps links.
3. All 1996 90/45 Mbps links have been increased to 564/274 links.

3.5.4 2010 IRN Links And Topology

The 2010 IRN links are listed in Exhibit ES-18. Again, the major access points and connectivity for the 2010 IRN are identical to those for the 2000 IRN. As before, the only changes that were made were in the link capacities.

The 2010 IRN topology is depicted in Exhibt ES-19. This topology map again looks identical to the topology map for the 2000 IRN, and as before, the link capacities have been increased in the following manner:

1. All 2000 5 Gbps links have been increased to 25 Gbps links.
2. All 2000 1 Gbps links have been increased to 5 Gbps links.
3. All 2000 564/274 Mbps links have been increased to 1 Gbps links.

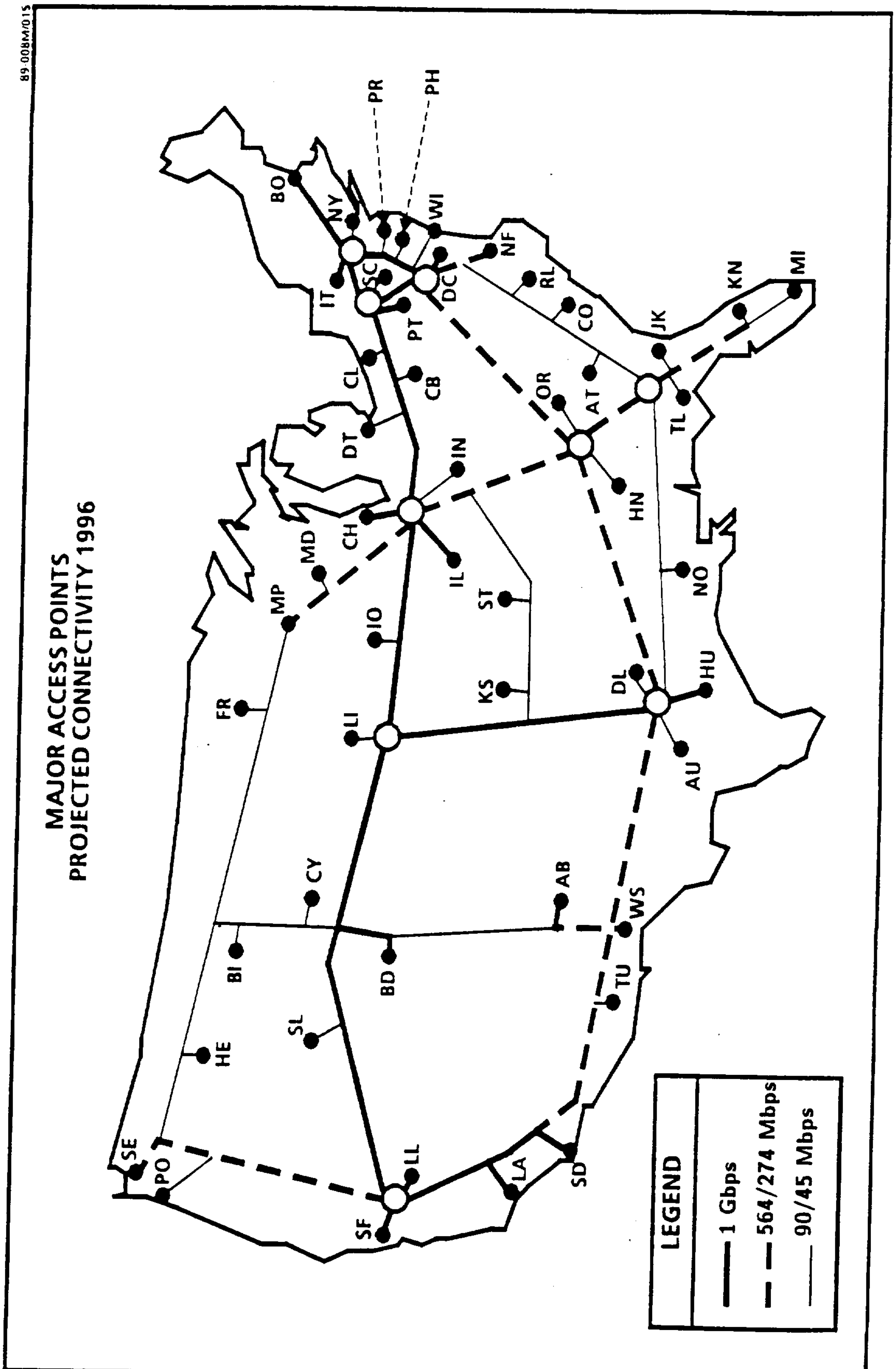

EXHIBIT ES-15. 1996 IRN Topology

YEAR 2000 IRN LINKS

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	1G
AT	ATLANTA	GA	CO	COLUMBIA	SC	565M
AT	ATLANTA	GA	TL	TALLAHASEE	FL	565M
AU	AUSTIN	TX	DL	DALLAS	TX	565M
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	565M
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	5G
BI	BILLINGS	MT	CY	CHEYENNE	WY	565M
BI	BILLINGS	MT	FR	FARGO	ND	565M
BO	BOSTON	MA	NY	NEW YORK	NY	5G
CB	COLUMBUS	OH	DT	DETROIT	MI	565M
CH	CHICAGO	IL	IL	URBANA	IL	5G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1G
CH	CHICAGO	IL	LI	LINCOLN	NE	5G
CH	CHICAGO	IL	DT	DETROIT	MI	565M
CH	CHICAGO	IL	ST	ST LOUIS	MO	565M
CL	CLEVELAND	OH	CB	COLUMBUS	OH	565M
CO	COLUMBIA	SC	RL	RALEIGH	NC	565M
CY	CHEYENNE	WY	BD	BOULDER	CO	565M
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	5G
DC	WASHINGTON	DC	NF	NORFOLK	VA	1G
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M
FR	FARGO	ND	MP	MINNEAPOLIS	MN	565M
HE	HELENA	MT	BI	BILLINGS	MT	565M
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	565M
HU	HOUSTON	TX	OR	OAK RIDGE	TN	1G
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	565M
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	565M
IT	ITHACA	NY	NY	NEW YORK	NY	5G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	565M
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	5G
LI	LINCOLN	NE	HU	HOUSTON	TX	5G
LI	LINCOLN	NE	BD	BOULDER	CO	5G
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M
MD	MADISON	WI	CH	CHICAGO	IL	1G
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	565M
NY	NEW YORK	NY	DC	WASHINGTON	DC	5G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	5G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	1G
PO	PORTLAND	OR	SE	SEATTLE	WA	565M
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M
PT	PITTSBURGH	PA	CH	CHICAGO	IL	5G
RL	RALEIGH	NC	NF	NORFOLK	VA	565M
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	565M
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	1G
SE	SEATTLE	WA	HE	HELENA	MT	565M
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	1G
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	5G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	5G
SL	SALT LAKE	UT	BD	BOULDER	CO	565M
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	565M
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	1G
TU	TUCSON	AZ	WS	WHITE SANDS	NM	565M

EXHIBIT ES-16. 2000 IRN Links & Capacity

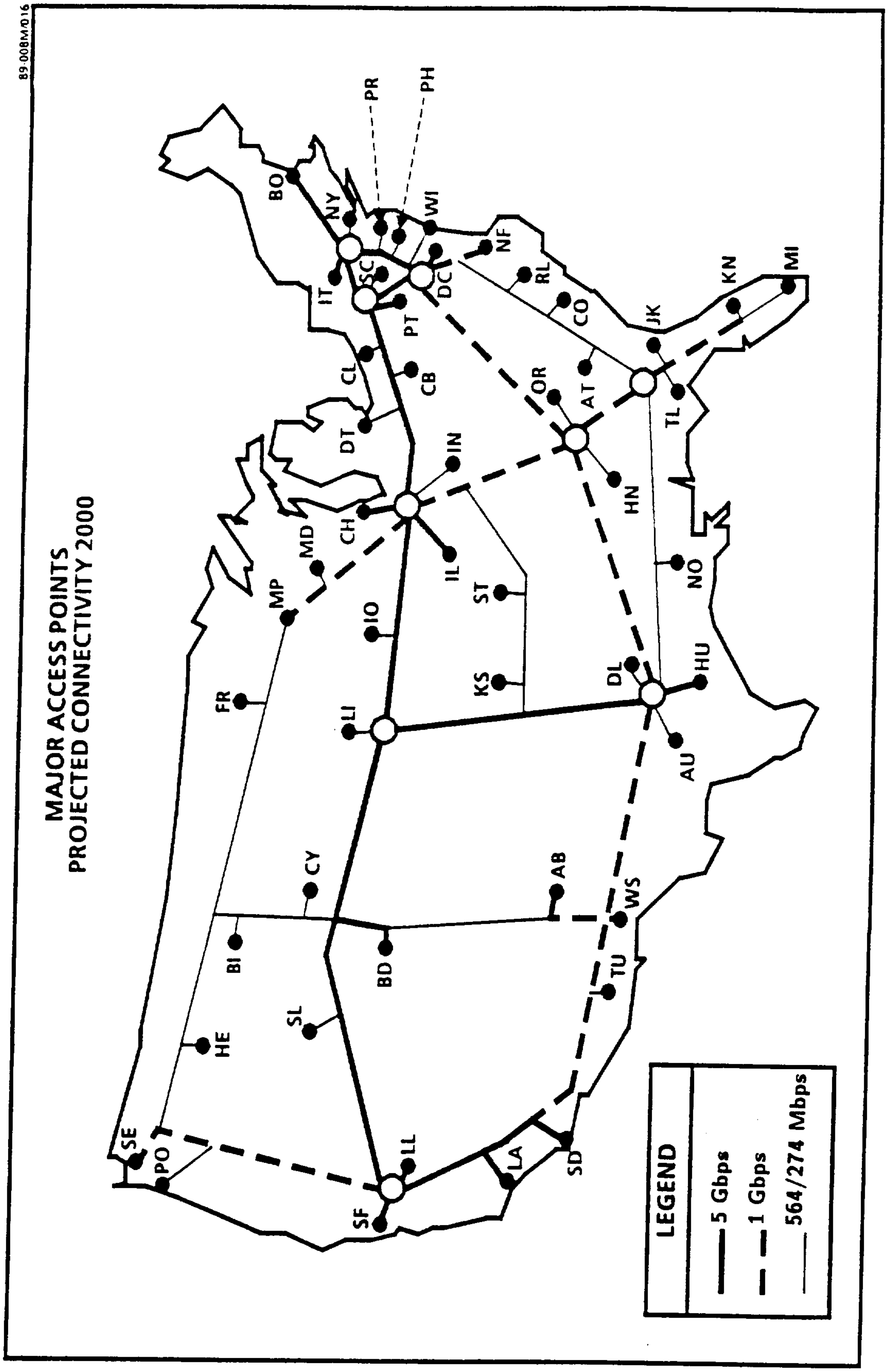

EXHIBIT ES-17. 2000 IRN Topology

YEAR 2010 IRN LINKS

ID	CITY -A	ST	ID	CITY - B	ST	CAPACITY
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	5G
AT	ATLANTA	GA	CO	COLUMBIA	SC	1G
AT	ATLANTA	GA	TL	TALLAHASEE	FL	1G
AU	AUSTIN	TX	DL	DALLAS	TX	1G
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	1G
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	25G
BI	BILLINGS	MT	CY	CHEYENNE	WY	1G
BI	BILLINGS	MT	FR	FARGO	ND	1G
BO	BOSTON	MA	NY	NEW YORK	NY	25G
CB	COLUMBUS	OH	DT	DETROIT	MI	1G
CH	CHICAGO	IL	IL	URBANA	IL	25G
CH	CHICAGO	IL	OR	OAK RIDGE	TN	5G
CH	CHICAGO	IL	LI	LINCOLN	NE	25G
CH	CHICAGO	IL	DT	DETROIT	MI	1G
CH	CHICAGO	IL	ST	ST LOUIS	MO	1G
CL	CLEVELAND	OH	CB	COLUMBUS	OH	1G
CO	COLUMBIA	SC	RL	RALEIGH	NC	1G
CY	CHEYENNE	WY	BD	BOULDER	CO	1G
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	25G
DC	WASHINGTON	DC	NF	NORFOLK	VA	5G
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G
FR	FARGO	ND	MP	MINNEAPOLIS	MN	1G
HE	HELENA	MT	BI	BILLINGS	MT	1G
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	1G
HU	HOUSTON	TX	OR	OAK RIDGE	TN	5G
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	1G
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	1G
IT	ITHACA	NY	NY	NEW YORK	NY	25G
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	1G
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	25G
LI	LINCOLN	NE	HU	HOUSTON	TX	25G
LI	LINCOLN	NE	BD	BOULDER	CO	25G
LI	LINCOLN	NE	IO	IOWA CITY	IA	1G
MD	MADISON	WI	CH	CHICAGO	IL	5G
MP	MINNEAPOLIS	MN	MD	MADISON	WI	5G
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	1G
NY	NEW YORK	NY	DC	WASHINGTON	DC	25G
NY	NEW YORK	NY	PT	PITTSBURGH	PA	25G
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	5G
PO	PORTLAND	OR	SE	SEATTLE	WA	1G
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G
PT	PITTSBURGH	PA	CH	CHICAGO	IL	25G
RL	RALEIGH	NC	NF	NORFOLK	VA	1G
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1G
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	5G
SE	SEATTLE	WA	HE	HELENA	MT	1G
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	5G
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	25G
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	25G
SL	SALT LAKE	UT	BD	BOULDER	CO	1G
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	1G
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	5G
TU	TUCSON	AZ	WS	WHITE SANDS	NM	1G

EXHIBIT ES-18. 2010 IRN Links & Capacity

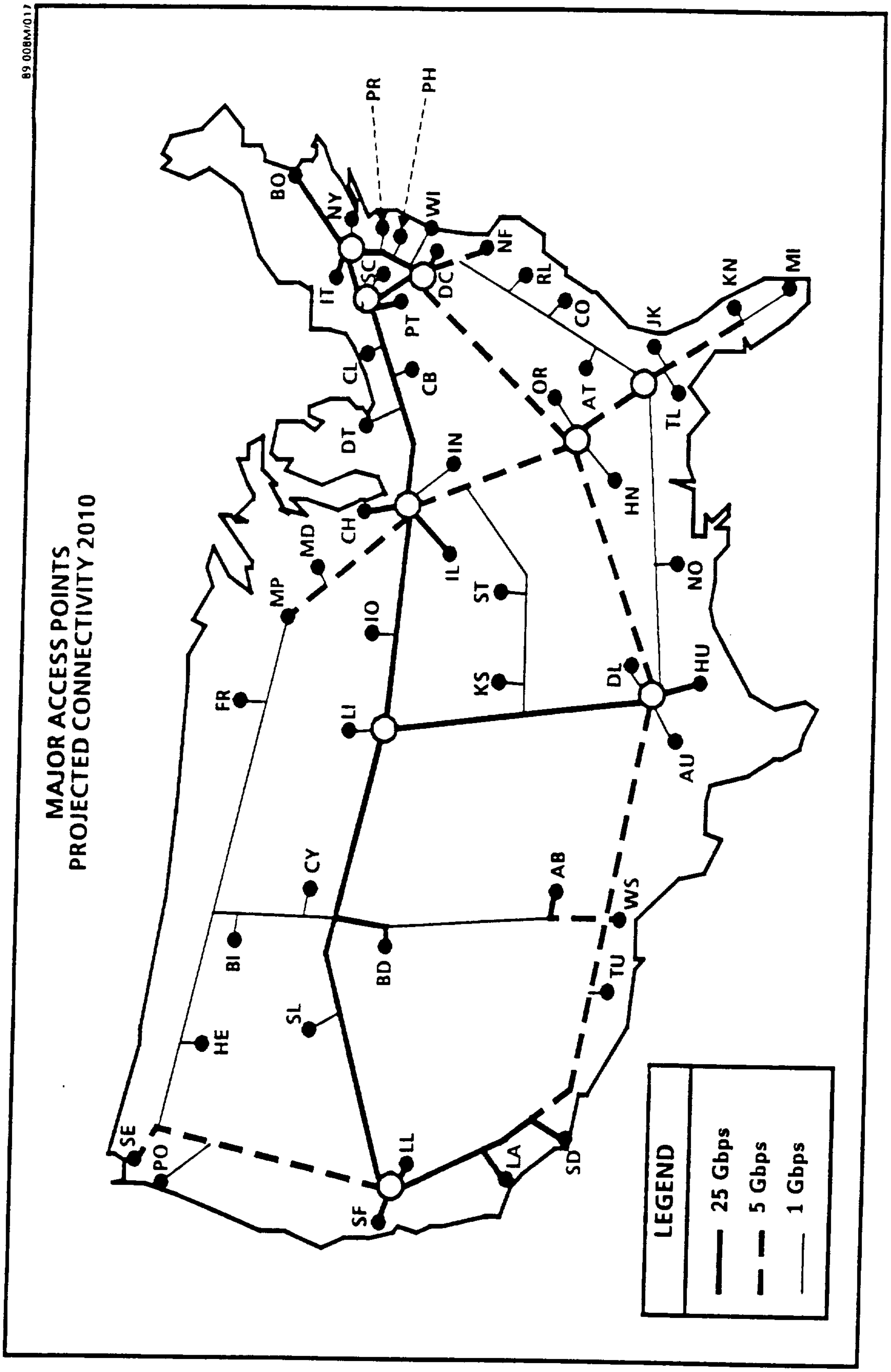

EXHIBIT ES-19. 2010 IRN Topology

3.6 ESTIMATES OF CURRENT AND FUTURE IRN COSTS

The major findings obtained from the activities conducted to estimate the current and future circuit costs of the IRN are presented in terms of the link costs and total costs for each of the selected benchmark years. In the following discussion of costs it was assumed that the IRN was not completely integrated in 1989 and 1991, but was so in 1996 and beyond.

3.6.1 Current (1989) IRN Circuit Costs

The circuit cost per month for each city-pair link and for the total Current (1989) IRN are shown in Exhibit ES-20. Again, the city-pairs are listed in the same order as they were listed in earlier exhibits listing the Current IRN links.

The concept of a "Megabit Per Second Mile" (MM) was developed to provide a measure of network efficiency across benchmark years. An MM refers to the movement of one Megabit Per Second of traffic one mile (i.e.,an MM is a Mbps Mile). The number of MMs is indicated for each city-pair link.

The total Current IRN monthly cost of about 86,000 MMs, was estimated to be about 1.4 million dollars.

3.6.2 1991 IRN Circuit Costs

The cost per month for each city-pair link and for the total 1991 IRN are shown in Exhibit ES-21. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 1991 IRN links and as they were listed in Exhibit ES-20 which showed 1989 IRN costs. City-pair cost changes from 1989 to 1991 occurred only where the increases in the NSFNET backbone link speeds caused IRN city-pair link speed increases, and therefore link cost increases.

The total 1991 IRN monthly cost of about 661,000 MMs, was estimated to be about 2.4 million dollars. That is, compared with 1989, almost eight times as much traffic is expected to be moved in 1991 at less than twice the 1989 cost.

COST PER MONTH - CALCULATED BY USING AN ESTIMATED AVERAGE COST PER MILE FOR THE VARIOUS SERVICES

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2.950.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1.327.84	14.300.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2.477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2.477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2.477.50
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2.950.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	34.44	2.337.50
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	37.58	2.477.50
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56	346	19.38	1.665.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544	180	277.92	4.100.00
BD	BOULDER	CO	MD	MADISON	WI	224	844	189.06	9.174.00
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1.501	336.22	14.758.50
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	19.66	1.677.50
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1.501	336.22	14.758.50
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1.772	396.93	17.062.00
BD	BOULDER	CO	MI	MIAMI	FL	224	1.742	390.21	16.807.00
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	34.66	2.347.50
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1.162	260.29	11.877.00
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	1.477.61	15.755.00
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	214.37	10.134.50
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	1.269.17	13.730.00
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	290.27	4.220.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	353.58	4.835.00
CH	CHICAGO	IL	SE	SEATTLE	WA	1544	1.733	2.675.75	27.395.00
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	365.93	4.955.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	365.93	4.955.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1.852	103.71	5.430.00
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	186.82	3.215.00
CH	CHICAGO	IL	BD	DENVER	CO	1544	927	1.431.29	15.305.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	45.14	2.815.00
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	193.00	3.275.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1544	475	733.40	8.525.00
CH	CHICAGO	IL	BO	CAMBRIDGE	MA	1544	848	1.309.31	14.120.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4.475.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1.646	92.18	4.915.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2.401	134.46	6.802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2.401	134.46	6.802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2.401	134.46	6.802.50
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	33.66	2.302.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1.065.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2.990.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	34.05	2.568.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	760	127.65	6.540.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2.292	128.35	6.530.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1.572	352.13	15.362.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1.721	96.38	5.102.50
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2.292	513.41	21.482.00

EXHIBIT ES-20. Current (1989) IRN Circuit Costs

DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2.292	128.35	6.530.00
DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	22.06	1.785.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	1544	165	254.76	3.875.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2.432	3.755.01	37.880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2.432	272.38	12.144.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2.432	544.77	22,672.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	1544	1.217	1.879.05	19,655.00
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2.292	1.026.82	35.780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2.292	641.75	26.456.00
DC	WASHINGTON	DC	LA	LOMPOC	CA	224	2,292	513.41	21.482.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10.415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	510.72	12.800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	307.71	10.415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	2048	1.217	2.492.42	29.482.50
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	6.94	1.110.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	8.79	1.192.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	212.80	10.380.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	11.48	1.312.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1.065.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	1.164.18	12.710.00
DT	ANN ARBOR	MI	CB	COLUMBUS	OH	1544	163	251.67	3.845.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	1544	459	708.70	6.285.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	1.153.02	14,767.50
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	103.49	5.604.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	403.87	10.415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	31.53	2.207.50
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	40.43	2.605.00
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	226.97	3.605.00
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	12.54	1.360.00
HU	HOUSTON	TX	HN	HUNTSVILLE	AL	56	616	34.50	2,340.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	700	39.20	2.550.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3.605.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1.167.50
HU	HOUSTON	TX	BD	BOULDER	CO	1544	899	1.388.06	14.885.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1.167.50
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	1.389.60	14.900.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3.275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	174.47	3.095.00
IL	URBANA	IL	MD	MILWAUKEE	WI	56	211	11.82	1.327.50
IN	INDIANAPOLIS	IN	CB	COLUMBUS	OH	1544	168	259.39	3.920.00
IO	IOWA CITY	IA	IL	URBANA	IL	1544	202	311.89	4.430.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	DC	WASHINGTON	DC	1544	291	449.30	5.765.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	1544	267	412.25	5.405.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1.446	80.98	4.415.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1.446	2.232.62	23.090.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544	671	1.036.02	11.465.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	664	1.025.22	11.360.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1.798	100.69	5.295.00

EXHIBIT ES-20. Current (1989) IRN Circuit Costs

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1.082.50
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1.082.50
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6.650.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1.376	77.06	4.240.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	46.03	2.855.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3.095.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6.650.00
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	24.86	1.910.00
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2.292	128.35	6.530.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1.376	231.17	10.544.00
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2.292	1.540.22	35.780.00
LI	LINCOLN	NE	IL	URBANA	IL	56	447	25.03	1.917.50
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	11.14	1.297.50
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	15.34	1.485.00
LI	LINCOLN	NE	BD	BOULDER	CO	1544	454	700.98	8.210.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	2.02	890.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2.507	3.870.81	39.005.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	17.98	1.602.50
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	1.327.84	14.300.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	375.19	5.045.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	358.21	4.880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	980.44	10.925.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	290.27	4.220.00
NY	NEW YORK	NY	IT	ROME	NY	1544	195	301.08	4.325.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	680.90	8.015.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	594.44	7.175.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2.080	3.211.52	32.600.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	415.34	5.435.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	1.059.18	11.690.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1.610	2.485.84	25.550.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	270.20	4.025.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	64.85	2.030.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4.835.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4.835.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	353.58	4.835.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	353.58	4.835.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	177.56	3.125.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	1544	285	440.04	5.675.00
PT	PITTSBURGH	PA	IL	URBANA	IL	1544	434	670.10	7.910.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	176.02	3.110.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	398.35	5.270.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	293.36	4.250.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3.095.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	6.33	1.082.50
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3.095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3.095.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	1544	1.305	2.014.92	20.975.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	1544	463	714.87	8.345.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	6.33	1.082.50

EXHIBIT ES-20. Current (1989) IRN Circuit Costs

(Continued)

SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1.068	59.81	3.470.00
SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	25.93	1.957.50
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	113	6.33	1.082.50
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2.360.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2.360.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	1544	1.068	1.548.99	17.420.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	1544	684	1.056.10	11.660.00
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	8.23	1.167.50
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	8.23	1.167.50
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	8.23	1.167.50
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	156.80	6,650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	55.58	1.940.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	52.19	3.130.00
SF	SAN FRANCISCO	CA	DC.	WASHINGTON	DC	336	2,432	817.15	33.200.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	19.60	1.675.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2.432	136.19	6.880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1.852	2,859.49	29.180.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	1544	598	923.31	10.370.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	1544	351	541.94	6.665.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	1544	1.256	1.939.26	20.240.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1.265	1.953.16	20.375.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	181.22	8.876.50
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1.265	283.36	12.752.50
sum						146824	133.734	85.529.58	1.417.122.00

EXHIBIT ES-20. Current (1989) IRN Circuit Costs

(Continued)

1991 PROJECTED COST

ID	CITY - A	ID	ID	CITY - B	ST	CAPACITY (KB)	MILES	MM	COST
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2.950.00
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	1544	860	1.327.84	14.300.00
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2.477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2.477.50
AB	ALBUQUERQUE	NM	KS	KANSAS CITY	KS	56	671	37.58	2.477.50
AB	ALBUQUERQUE	NM	LL	LIVERMORE	CA	56	860	48.16	2.950.00
AB	LOS ALAMOS	NM	AU	AUSTIN	TX	56	615	34.44	2.337.50
AB	LOS ALAMOS	NM	KS	LAWRENCE	KS	56	671	37.58	2.477.50
AB	LOS ALAMOS	NM	BD	BOULDER	CO	56	346	19.38	1.665.00
AU	AUSTIN	TX	DL	RICHARDSON	TX	1544	180	277.92	4.100.00
BD	BOULDER	CO	MD	MADISON	WI	224	844	189.06	9.174.00
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1.501	336.22	14.758.50
BD	BOULDER	CO	SL	SALT LAKE CITY	UT	56	351	19.66	1.677.50
BD	BOULDER	CO	DC	WASHINGTON	DC	224	1.501	336.22	14.758.50
BD	BOULDER	CO	BO	WOODS HOLE	MA	224	1.772	396.93	17.062.00
BD	BOULDER	CO	MI	MIAMI	FL	224	1.742	390.21	16.807.00
BD	BOULDER	CO	TU	TUCSON	AZ	56	619	34.66	2.347.50
BD	BOULDER	CO	DT	ANN ARBOR	MI	224	1.162	260.29	11.877.00
BD	BOULDER	CO	PO	CORVALIS	OR	1544	957	1.477.61	15.755.00
BD	BOULDER	CO	PO	CORVALLIS	OR	224	957	214.37	10.134.50
BD	DENVER	CO	LA	LOS ANGELES	CA	1544	822	1.269.17	13.730.00
BO	BOSTON	MA	NY	NEW YORK	NY	1544	188	290.27	4.220.00
BO	CAMBRIDGE	MA	PR	PRINCETON	NJ	1544	229	353.58	4.835.00
CH	CHICAGO	IL	SE	SEATTLE	WA	44M	1.733	77.527.49	158.970.00
CH	CHICAGO	IL	DT	LANSING	MI	1544	237	365.93	4.955.00
CH	CHICAGO	IL	DT	LITCHFIELD	MI	1544	237	365.93	4.955.00
CH	CHICAGO	IL	SF	SAN FRANCISCO	CA	56	1.852	103.71	5.430.00
CH	CHICAGO	IL	MD	MADISON	WI	1544	121	186.82	3.215.00
CH	CHICAGO	IL	BD	DENVER	CO	44M	927	41.470.27	86.430.00
CH	CHICAGO	IL	TL	TALLAHASSEE	FL	56	806	45.14	2.815.00
CH	CHICAGO	IL	IL	URBANA	IL	1544	125	193.00	3.275.00
CH	CHICAGO	IL	LI	LINCOLN	NE	44M	475	21.249.60	45.750.00
CH	CHICAGO	IL	BC	CAMBRIDGE	MA	1544	848	1.309.31	14.120.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	1544	205	316.52	4.475.00
DC	WASHINGTON	DC	AB	ALBUQUERQUE	NM	56	1.646	92.18	4.915.00
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2.401	134.46	5.802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2.401	134.46	5.802.50
DC	WASHINGTON	DC	LL	LIVERMORE	CA	56	2.401	134.46	5.802.50
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	56	601	33.66	2.302.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1.065.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1544	106	163.66	2.990.00
DC	WASHINGTON	DC	CL	CLEVELAND	OH	112	304	34.05	2.568.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	168	760	127.68	6.540.00
DC	WASHINGTON	DC	LA	LOS ANGELES	CA	56	2.292	128.35	6.530.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	224	1.571	352.13	15.362.00
DC	WASHINGTON	DC	WS	WHITE SANDS	NM	56	1.572	88.03	4.730.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	224	2.292	513.41	21.482.00
DC	WASHINGTON	DC	LA	BARSTOW	CA	56	2.292	128.35	6.530.00

EXHIBIT ES-21. 1991 IRN Circuit Costs

DC	WASHINGTON	DC	BO	CAMBRIDGE	MA	56	394	22.06	1.785.00
DC	WASHINGTON	DC	PR	PRINCETON	NJ	44M	165	7.381.44	17,850.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	1544	2.432	3.755.01	37,880.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	112	2.432	272.38	12.144.00
DC	WASHINGTON	DC	SF	SAN FRANCISCO	CA	224	2.432	544.77	22.672.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	44M	1.217	54.443.71	112,530.00
DC	WASHINGTON	DC	LA	PASADENA	CA	448	2.292	1.026.82	35,780.00
DC	WASHINGTON	DC	LA	PASADENA	CA	280	2.292	641.76	26,466.00
DC	WASHINGTON	DC.	LA	LOMPOC	CA	224	2,292	513.41	21.482.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	1544	601	927.94	10,415.00
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	672	760	510.72	12.800.00
DC	WASHINGTON	DC	HN	HUNTSVILLE	AL	512	601	307.71	10.415.00
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1.217	68.15	3.842.50
DC	WASHINGTON .	DC	HU	HOUSTON	TX	2048	1,217	2.492.42	29.482.50
DC	WASHINGTON	DC	PH	WILMINGTON	DE	56	124	6.94	1.110.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	56	157	8.79	1.192.50
DC	WASHINGTON	DC	HU	HOUSTON	TX	56	1,217	68.15	3,842.50
DC	WASHINGTON	DC	KN	CAPE KENNEDY	FL	280	760	212.80	10.380.00
DC	WASHINGTON	DC	NY	NEW YORK	NY	56	205	11.48	1.312.50
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	56	106	5.94	1.065.00
DL	RICHARDSON	TX	TL	TALLAHASSEE	FL	1544	754	1.164.18	12.710.00
DT	ANN ARBOR	MI	CE	COLUMBUS	OH	1544	163	251.67	3,845.00
DT	ANN ARBOR	MI	PR	PRINCETON	NJ	44M	459	20.533.82	44.310.00
HN	HUNTSVILLE	AL	KN	CAPE KENNEDY	FL	2048	563	1,153.02	14.767.50
HN	HUNTSVILLE	AL	HU	HOUSTON	TX	168	616	103.49	5,604.00
HN	HUNTSVILLE	AL	DC	WASHINGTON	DC	672	601	403.87	10,415.00
HN	HUNTSVILLE	AL	KN	ORLANDO	FL	56	563	31.53	2.207.50
HN	HUNTSVILLE	AL	MI	MIAMI	FL	56	722	40.43	2.605.00
HU	BRYAN	TX	AU	AUSTIN	TX	1544	147	226.97	3.605.00
HU	HOUSTON	TX	DL	DALLAS	TX	56	224	12.54	1.360.00
HU	HOUSTON	.TX	HN	HUNTSVILLE	AL	56	616	34.50	2.340.00
HU	HOUSTON	TX	WS	WHITE SANDS	NM	56	500	28.00	2.050.00
HU	HOUSTON	TX	AU	AUSTIN	TX	1544	147	226.97	3.605.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1.167.50
HU	HOUSTON	TX	BD	BOULDER	CO	44M	899	40.217.66	83.910.00
HU	HOUSTON	TX	AU	AUSTIN	TX	56	147	8.23	1.167.50
HU	HOUSTON	TX	KN	CAPE KENNEDY	FL	1544	900	1.389.60	14.900.00
IL	URBANA	IL	CH	CHICAGO	IL	1544	125	193.00	3.275.00
IL	URBANA	IL	IN	BLOOMINGTON	IN	1544	113	174.47	3.095.00
IL	URBANA	IL	MP	MILWAUKEE	WI	56	211	11.82	1.327.50
IN	INDIANAPOLIS	IN	CE	COLUMBUS	OH	1544	168	259.39	3.920.00
IC	IOWA CITY	IA	IL	URBANA	IL	1544	202	311.89	4.430.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	NY	NEW YORK	NY	1544	195	301.08	4.325.00
IT	ITHACA	NY	DC	WASHINGTON	DC	44M	291	13.018.18	29.190.00
IT	ITHACA	NY	PT	PITTSBURGH	PA	44M	267	11.944.51	27.030.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	56	1.446	80.98	4.415.00
KS	KANSAS CITY	KS	LL	LIVERMORE	CA	1544	1.446	2.232.62	23.090.00
KS	KANSAS CITY	KS	AB	ALBUQUERQUE	NM	1544	671	1.036.02	11.465.00
LA	LOS ANGELES	CA	AB	LOS ALAMOS	NM	1544	564	1.025.22	11.360.00
LA	LOS ANGELES	CA	HN	HUNTSVILLE	AL	56	1.798	100.69	5.295.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1.082.50

EXHIBIT ES-21. 1991 IRN Circuit Costs

(Continued)

LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	56	113	6.33	1.082.50
LA	LOS ANGELES	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6.650.00
LA	LOS ANGELES	CA	HU	HOUSTON	TX	56	1.376	77.06	4.240.00
LA	LOS ANGELES	CA	BD	BOULDER	CO	56	822	46.03	2.855.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1544	113	174.47	3.095.00
LA	LOS ANGELESO	CA	SF	SAN FRANCISCO	CA	1544	350	540.40	6.650.00
LA	PASADENA	CA	TU	TUCSON	AZ	56	444	24.86	1.910.00
LA	PASADENA	CA	DC	BALTIMORE	MD	56	2.292	128.35	6.530.00
LA	PASADENA	CA	HU	HOUSTON ISLAND	TX	168	1.376	231.17	10.544.00
LA	PASADENA	CA	DC	WASHINGTON	DC	672	2.292	1.540.22	35.780.00
LI	LINCOLN	NE	IL	URBANA	IL	56	447	25.03	1.917.50
LI	LINCOLN	NE	KS	LAWRENCE	KS	56	199	11.14	1.297.50
LI	LINCOLN	NE	IO	IOWA CITY	IA	56	274	15.34	1.485.00
LI	LINCOLN	NE	BD	BOULDER	CO	44M	454	20.310.14	43.860.00
LL	LIVERMORE	CA	SF	OAKLAND	CA	56	36	2.02	890.00
LL	LIVERMORE	CA	PR	PRINCETON	NJ	1544	2.507	3.870.81	39.005.00
LL	LIVERMORE	CA	LA	LOS ANGELES	CA	56	321	17.98	1.602.50
LL	LIVERMORE	CA	AB	ALBUQUERQUE	NM	1544	860	1.327.84	14.300.00
MP	MINNEAPOLIS	MN	IO	IOWA CITY	IA	1544	243	375.19	5.045.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1544	232	358.21	4.880.00
NF	NORFOLK	VA	TL	TALLAHASSEE	FL	1544	635	980.44	10.925.00
NY	LONG ISLAND	NY	BO	CAMBRIDGE	MA	1544	188	290.27	4.220.00
NY	NEW YORK	NY	IT	ROME	NY	1544	195	301.08	4.325.00
OR	OAK RIDGE	TN	CH	CHICAGO	IL	1544	441	680.90	9.015.00
OR	OAK RIDGE	TN	TL	TALLAHASSEE	FL	1544	385	594.44	7.175.00
PR	PRINCETON	NJ	TU	TUCSON	AZ	1544	2.080	3.211.52	32.600.00
PR	PRINCETON	NJ	NF	NORFOLK VA	DC	1544	269	415.34	5.435.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	CH	CHICAGO	IL	1544	686	1.059.18	11.690.00
PR	PRINCETON	NJ	NY	LONG ISLAND	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	BD	BOLDER	CO	1544	1.610	2.485.84	25.550.00
PR	PRINCETON	NJ	SC	STATE COLLEGE	PA	1544	175	270.20	4.025.00
PR	PRINCETON	NJ	PH	PHILADELPHIA	PA	1544	42	64.85	2.030.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4.835.00
PR	PRINCETON	NJ	BO	CAMBRIDGE	MA	1544	229	353.58	4.835.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	NY	NEW YORK	NY	1544	40	61.76	2.000.00
PR	PRINCETON	NJ	BO	NEW HAVEN	CT	1544	229	353.58	4.835.00
PR	PRINCETON	NJ	BO	AMHERST	MA	1544	229	353.58	4.835.00
PT	PITTSBURGH	PA	SC	STATE COLLEGE	PA	1544	115	177.56	3.125.00
PT	PITTSBURGH	PA	PR	PRINCETON	NJ	44M	285	12.749.76	28.550.00
PT	PITTSBURGH	PA	IL	URBANA	IL	44M	434	19.415.42	42.060.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1544	114	176.02	3.110.00
PT	PITTSBURGH	PA	PH	PHILADELPHIA	PA	1544	258	398.35	5.270.00
PT	PITTSBURGH	PA	DC	WASHINGTON	DC	1544	190	293.36	4.250.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3.095.00
SD	SAN DIEGO	CA	LA	RIVERSIDE	CA	56	113	6.33	1.082.50
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3.095.00
SD	SAN DIEGO	CA	LA	LOS ANGELES	CA	1544	113	174.47	3.095.00
SD	SAN DIEGO	CA	HU	HOUSTON	TX	44M	1.305	58.380.48	120.450.00
SD	SAN DIEGO	CA	SF	MENLO PARK	CA	44M	463	20.712.77	44.670.00
SD	SAN DIEGO	CA	LA	SANTA BARBARA	CA	56	113	6.33	1.082.50
SD	SAN DIEGO	CA	SE	SEATTLE	WA	56	1.068	59.81	3.470.00

EXHIBIT ES-21. 1991 IRN Circuit Costs

(Continued)

SD	SAN DIEGO	CA	SF	OAKLAND	CA	56	463	25.93	1.957.50
SD	SAN DIEGO	CA	LA	IRVINE	CA	56	112	6.33	1,082.50
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2.360.00
SD	SAN DIEGO	CA	SL	SALT LAKE CITY	UT	56	624	34.94	2.360.00
SE	SEATTLE	WA	SD	SAN DIEGO	CA	44M	1,068	47.778.05	99.120.00
SE	SEATTLE	WA	SF	MENLO PARK	CA	44M	684	30.599.42	64.560.00
SE	SEATTLE	WA	PO	PORTLAND	OR	56	147	8.23	1.167.50
SE	SEATTLE	WA	PO	CORVALLIS	OR	56	147	8.23	1.167.50
SE	SEATTLE	WA	PO	EUGENE	OR	56	147	8.23	1.167.50
SF	SAN FRANCISCO	CA	LA	PASADENA	CA	448	350	156.80	6.650.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1544	36	55.58	1.940.00
SF	SAN FRANCISCO	CA	BD	BOULDER	CO	56	932	52.19	3.130.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	336	2.432	917.15	33.200.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	56	350	19.60	1.675.00
SF	SAN FRANCISCO	CA	DC	WASHINGTON	DC	56	2.432	136.19	6.880.00
SF	SAN FRANCISCO	CA	CH	CHICAGO	IL	1544	1.852	2.859.49	29.180.00
SL	SALT LAKE CITY	UT	SF	MENLO PARK	CA	44M	598	26.752.13	56.820.00
SL	SALT LAKE CITY	UT	BD	BOULDER	CO	44M	351	15.702.34	34.590.00
SL	SALT LAKE CITY	UT	CH	CHICAGO	IL	44M	1,256	56.188.42	116.040.00
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	1544	1,265	1.953.16	20,375.00
WI	WALLOPS ISLAND	VA	MD	MADISON	WI	224	809	181.22	8.876.50
WI	WALLOPS ISLAND	VA	HU	HOUSTON	TX	224	1,265	283.36	12,752.50
sum							133.385	661.302.57	2,446.474.50

EXHIBIT ES-21. 1991 IRN Circuit Costs

(Continued)

3.6.3 1996 IRN Circuit Costs

The cost per month for each city-pair link and for the total 1996 IRN are shown in Exhibit ES-22. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 1996 IRN links.

The total 1996 IRN monthly cost of about eight and one-half million MMs was estimated to be about 6 million dollars. That is, compared with 1991, about thirteen times as much traffic is expected to be moved for only about two and one-half times the 1991 cost.

3.6.4 2000 IRN Circuit Costs

The circuit costs per month for each city-pair link and for the total 2000 IRN are shown in Exhibit ES-23. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 2000 IRN links and as they were listed in Exhibit ES-22 which showed the 1996 costs.

The total 2000 IRN monthly cost of about 35 million MMs was estimated to be about 16 million dollars. That is, compared with 1996, about four times as much traffic is expected to be moved in 2000 for about two and one-half times the 1996 cost.

3.6.5 2010 IRN Costs

The circuit costs per month for each city-pair link and for the total 2010 IRN are shown in Exhibit ES-24. The city-pairs are listed in the same order as they were listed in earlier exhibits listing the 2010 IRN links and as they were listed in Exhibit ES-23 which showed the 2000 costs.

The total 2010 IRN monthly cost of about 162 million MMs was estimated to be about 29 million dollars. That is, compared with 2000, about four and one-half times as much traffic is expected to be moved for less than two times the 2000 cost.

1996 PROJECTED COST

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	565M	754	426,010.00	343,800.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	90M	193	17,408.60	34,766.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	90M	233	21,016.60	41,246.00
AU	AUSTIN	TX	DL	DALLAS	TX	90M	180	16,236.00	32,660.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	90M	346	31,209.20	59,552.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	1G	932	1,053,160.00	508,280.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	90M	368	33,193.60	63,116.00
BI	BILLINGS	MT	FR	FARGO	ND	90M	565	50,963.00	95,030.00
BO	BOSTON	MA	NY	NEW YORK	NY	1G	297	335,610.00	165,380.00
CB	COLUMBUS	OH	DT	DETROIT	MI	90M	163	14,702.60	29,906.00
CH	CHICAGO	IL	IL	URBANA	IL	1G	125	141,250.00	72,500.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	565M	441	249,165.00	202,950.00
CH	CHICAGO	IL	LI	LINCOLN	NE	1G	475	536,750.00	261,500.00
CH	CHICAGO	IL	DT	DETROIT	MI	90M	237	21,377.40	41,894.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	90M	260	23,452.00	45,620.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	90M	126	11,365.20	23,912.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	90M	183	16,506.60	33,146.00
CY	CHEYENNE	WY	BD	BOULDER	CO	90M	80	7,216.00	16,460.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	1G	190	214,700.00	107,600.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	565M	157	88,705.00	75,150.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	90M	106	9,561.20	20,672.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	90M	214	19,302.80	38,168.00
HE	HELENA	MT	BI	BILLINGS	MT	90M	178	16,055.60	32,336.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	90M	162	14,612.40	29,744.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	565M	777	439,005.00	354,150.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	90M	320	28,864.00	55,340.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	90M	164	14,792.80	30,068.00
IT	ITHACA	NY	NY	NEW YORK	NY	1G	195	220,350.00	110,300.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	90M	176	15,875.20	32,012.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	1G	113	127,690.00	66,020.00
LI	LINCOLN	NE	HU	HOUSTON	TX	1G	759	857,670.00	414,860.00
LI	LINCOLN	NE	BD	BOULDER	CO	1G	454	513,020.00	250,160.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	90M	274	24,714.80	47,888.00
MD	MADISON	WI	CH	CHICAGO	IL	565M	121	68,365.00	58,950.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	565M	232	131,080.00	108,900.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	90M	348	31,389.60	59,876.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	1G	236	266,680.00	132,440.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	1G	207	233,910.00	116,780.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	565M	385	217,525.00	177,750.00
PO	PORTLAND	OR	SE	SEATTLE	WA	90M	147	13,259.40	27,314.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	90M	114	10,282.80	21,968.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	1G	409	462,170.00	225,860.00
RL	RALEIGH	NC	NF	NORFOLK	VA	90M	149	13,439.80	27,638.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	90M	115	10,373.00	22,130.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	565M	623	351,995.00	284,850.00
SE	SEATTLE	WA	HE	HELENA	MT	90M	489	44,107.80	82,718.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	565M	684	386,460.00	312,300.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	1G	36	40,680.00	24,440.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	1G	350	395,500.00	194,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	90M	351	31,660.20	60,362.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	90M	269	24,263.80	47,078.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	565M	264	149,160.00	123,300.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	90M	440	39,688.00	74,780.00
sum							16,166	8,533,500.00	5,919,620.00

EXHIBIT ES-22. 1996 IRN Circuit Costs

YEAR 2000 PROJECTED COST

ID	CITY - A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	1G	754	852,020.00	412,160.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	565M	193	109,045.00	91,350.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	565M	233	131,645.00	109,350.00
AU	AUSTIN	TX	DL	DALLAS	TX	565M	180	101,700.00	85,500.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	565M	346	195,490.00	160,200.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	5G	932	5,055,168.00	2,021,120.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	565M	368	207,920.00	170,100.00
BI	BILLINGS	MT	FR	FARGO	ND	565M	565	319,225.00	258,750.00
BO	BOSTON	MA	NY	NEW YORK	NY	5G	297	1,610,928.00	649,520.00
CB	COLUMBUS	OH	DT	DETROIT	MI	565M	163	92,095.00	77,850.00
CH	CHICAGO	IL	IL	URBANA	IL	5G	125	678,000.00	278,000.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	1G	441	498,330.00	243,140.00
CH	CHICAGO	IL	LI	LINCOLN	NE	5G	475	2,576,400.00	1,034,000.00
CH	CHICAGO	IL	DT	DETROIT	MI	565M	237	133,905.00	111,150.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	565M	260	146,900.00	121,500.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	565M	126	71,190.00	61,200.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	565M	183	103,395.00	86,850.00
CY	CHEYENNE	WY	BD	BOULDER	CO	565M	80	45,200.00	40,500.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	5G	190	1,030,560.00	418,400.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	1G	157	177,410.00	89,780.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	565M	106	59,890.00	52,200.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	565M	214	120,910.00	100,800.00
HE	HELENA	MT	BI	BILLINGS	MT	565M	178	100,570.00	84,600.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	565M	162	91,530.00	77,400.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	1G	777	878,010.00	424,580.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	565M	320	180,800.00	148,500.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	565M	164	92,660.00	78,300.00
IT	ITHACA	NY	NY	NEW YORK	NY	5G	195	1,057,680.00	429,200.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	565M	176	99,440.00	83,700.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	5G	113	612,912.00	252,080.00
LI	LINCOLN	NE	HU	HOUSTON	TX	5G	759	4,116,816.00	1,647,440.00
LI	LINCOLN	NE	BD	BOULDER	CO	5G	454	2,462,496.00	988,640.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	565M	274	154,810.00	127,800.00
MD	MADISON	WI	CH	CHICAGO	IL	1G	121	136,730.00	70,340.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	1G	232	262,160.00	130,280.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	565M	348	196,620.00	161,100.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	5G	236	1,280,064.00	517,760.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	5G	207	1,122,768.00	455,120.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	1G	385	435,050.00	212,900.00
PO	PORTLAND	OR	SE	SEATTLE	WA	565M	147	83,055.00	70,650.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	565M	114	64,410.00	55,800.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	5G	409	2,218,416.00	891,440.00
RL	RALEIGH	NC	NF	NORFOLK	VA	565M	149	84,185.00	71,550.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	565M	115	64,975.00	56,250.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	1G	623	703,990.00	341,420.00
SE	SEATTLE	WA	HE	HELENA	MT	565M	489	276,285.00	224,550.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	1G	684	772,920.00	374,360.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	5G	36	195,264.00	85,760.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	5G	350	1,898,400.00	764,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	565M	351	198,315.00	162,450.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	565M	269	151,985.00	125,550.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	1G	264	298,320.00	147,560.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	565M	440	248,600.00	202,500.00
sum							16,166	34,857,562.00	16,137,000.00

EXHIBIT ES-23. 2000 IRN Circuit Costs

YEAR 2010 PROJECTED COST

ID	CITY -A	ST	ID	CITY - B	ST	CAPACITY	MILES	MM	COST
AB	ALBUQUERQUE	NM	HU	HOUSTON	TX	5G	754	4,089,696.00	1,636,640.00
AT	ATLANTA	GA	CO	COLUMBIA	SC	1G	193	218,090.00	109,220.00
AT	ATLANTA	GA	TL	TALLAHASEE	FL	1G	233	263,290.00	130,820.00
AU	AUSTIN	TX	DL	DALLAS	TX	1G	180	203,400.00	102,200.00
BD	BOULDER	CO	AB	ALBUQUERQUE	NM	1G	346	390,980.00	191,840.00
BD	BOULDER	CO	SF	SAN FRANCISCO	CA	25G	932	25,275,840.00	3,029,680.00
BI	BILLINGS	MT	CY	CHEYENNE	WY	1G	368	415,840.00	203,720.00
BI	BILLINGS	MT	FR	FARGO	ND	1G	565	638,450.00	310,100.00
BO	BOSTON	MA	NY	NEW YORK	NY	25G	297	8,054,640.00	972,280.00
CB	COLUMBUS	OH	DT	DETROIT	MI	1G	163	184,190.00	93,020.00
CH	CHICAGO	IL	IL	URBANA	IL	25G	125	3,390,000.00	415,000.00
CH	CHICAGO	IL	OR	OAK RIDGE	TN	5G	441	2,391,984.00	960,560.00
CH	CHICAGO	IL	LI	LINCOLN	NE	25G	475	12,882,000.00	1,549,000.00
CH	CHICAGO	IL	DT	DETROIT	MI	1G	237	267,810.00	132,980.00
CH	CHICAGO	IL	ST	ST LOUIS	MO	1G	260	293,800.00	145,400.00
CL	CLEVELAND	OH	CB	COLUMBUS	OH	1G	126	142,380.00	73,040.00
CO	COLUMBIA	SC	RL	RALEIGH	NC	1G	183	206,790.00	103,820.00
CY	CHEYENNE	WY	BD	BOULDER	CO	1G	80	90,400.00	48,200.00
DC	WASHINGTON	DC	PT	PITTSBURGH	PA	25G	190	5,152,800.00	625,600.00
DC	WASHINGTON	DC	NF	NORFOLK	VA	5G	157	851,568.00	347,120.00
DC	WASHINGTON	DC	WI	WALLOPS ISLAND	VA	1G	106	119,780.00	62,240.00
FR	FARGO	ND	MP	MINNEAPOLIS	MN	1G	214	241,820.00	120,560.00
HE	HELENA	MT	BI	BILLINGS	MT	1G	178	201,140.00	101,120.00
HN	HUNTSVILLE	AL	OR	OAK RIDGE	TN	1G	162	183,060.00	92,480.00
HU	HOUSTON	TX	OR	OAK RIDGE	TN	5G	777	4,214,448.00	1,686,320.00
HU	HOUSTON	TX	NO	NEW ORLEANS	LA	1G	320	361,600.00	177,800.00
IN	INDIANAPOLIS	IN	CH	CHICAGO	IL	1G	164	185,320.00	93,560.00
IT	ITHACA	NY	NY	NEW YORK	NY	25G	195	5,288,400.00	641,800.00
KN	KENNEDY SPC CTR	FL	MI	MIAMI	FL	1G	176	198,880.00	100,040.00
LA	LOS ANGELES	CA	SD	SAN DIEGO	CA	25G	113	3,064,560.00	376,120.00
LI	LINCOLN	NE	HU	HOUSTON	TX	25G	759	20,584,080.00	2,469,160.00
LI	LINCOLN	NE	BD	BOULDER	CO	25G	454	12,312,480.00	1,480,960.00
LI	LINCOLN	NE	IO	IOWA CITY	IA	1G	274	309,620.00	152,960.00
MD	MADISON	WI	CH	CHICAGO	IL	5G	121	656,304.00	269,360.00
MP	MINNEAPOLIS	MN	MD	MADISON	WI	5G	232	1,258,368.00	509,120.00
NO	NEW ORLEANS	LA	TL	TALLAHASEE	FL	1G	348	393,240.00	192,920.00
NY	NEW YORK	NY	DC	WASHINGTON	DC	25G	236	6,400,320.00	774,640.00
NY	NEW YORK	NY	PT	PITTSBURGH	PA	25G	207	5,613,840.00	680,680.00
OR	OAK RIDGE	TN	TL	TALLAHASEE	FL	5G	385	2,088,240.00	839,600.00
PO	PORTLAND	OR	SE	SEATTLE	WA	1G	147	166,110.00	84,380.00
PT	PITTSBURGH	PA	CL	CLEVELAND	OH	1G	114	128,820.00	66,560.00
PT	PITTSBURGH	PA	CH	CHICAGO	IL	25G	409	11,092,080.00	1,335,160.00
RL	RALEIGH	NC	NF	NORFOLK	VA	1G	149	168,370.00	85,460.00
SC	STATE COLLEGE	PA	PT	PITTSBURGH	PA	1G	115	129,950.00	67,100.00
SD	SAN DIEGO	CA	AB	ALBUQUERQUE	NM	5G	623	3,379,152.00	1,353,680.00
SE	SEATTLE	WA	HE	HELENA	MT	1G	489	552,570.00	269,060.00
SE	SEATTLE	WA	SF	SAN FRANCISCO	CA	5G	684	3,710,016.00	1,485,440.00
SF	SAN FRANCISCO	CA	LL	LIVERMORE	CA	25G	36	976,320.00	126,640.00
SF	SAN FRANCISCO	CA	LA	LOS ANGELES	CA	25G	350	9,492,000.00	1,144,000.00
SL	SALT LAKE	UT	BD	BOULDER	CO	1G	351	396,630.00	194,540.00
ST	ST LOUIS	MO	KS	KANSAS CITY	MO	1G	269	303,970.00	150,260.00
TL	TALLAHASEE	FL	KN	KENNEDY SPC CTR	FL	5G	264	1,431,936.00	578,240.00
TU	TUCSON	AZ	WS	WHITE SANDS	NM	1G	440	497,200.00	242,600.00
sum							16,166	161,504,572.00	29,184,800.00

EXHIBIT ES-24. 2010 IRN Circuit Costs

3.6.6 Summary Of Circuit Costs

The monthly circuit costs and the cost per MM for each benchmark year that were discussed above are summarized in Exhibit ES-25.

In addition to providing a summary of the circuit costs discussed above, Exhibit ES-25 also presents a summary of the circuit costs for the benchmark years 1996, 2000 and 2010, assuming that the IRN does not become integrated. These additional costs were developed so that the cost implications of not integrating the IRN could be determined. These cost were developed by first applying growth rates to the individual network links in the 1991 IRN. That is, the same network links that were costed for 1989 and 1991 were costed for 1996, 2000 and 2010. For each benckmark year, a link's capacity was increased to a capacity one step above its capacity for the previous benchmark year, using the following step increases in capacity: 56 Kbps, 1.544 Mbps, 45 Mbps, 565 Mbps, 1 Gbps, and 5 Gbps. These growth projections resulted in non-integrated IRNs for 1996, 2000 and 2010 with total capacities about equal to the capacities of the integrated IRNs for 1996, 2000, and 2010.

Assuming a non-integrated IRN is 1989 and 1991 and an integrated IRN in 1996 and beyond (i.e, the expected scenario), the IRN monthly circuit cost increases from 1989 to 2010 by about a factor of 20, while the capacity increases by about a factor of 1800. That is, the cost per month per MM in 2010 is only about 1/90 of the cost in 1989. This drop in cost is diagrammed in Exhibit 1-26. The cost per MM drops from about $16.50/MM in 1989 to about $ .18/MM in 2010.

The implications of not integrating the IRN in 1996 and beyond are diagrammed in Exhibits ES-27 and ES-28. Exhibit ES-27 shows that the non-integrated IRN cost per month per MM is about double the integrated IRN cost in 1996. It is tripple the cost in 2010. These cost implications of not integrating the IRN are dramatized even more in Exhibit ES-28. The integrated IRN monthly circuit costs are about five million dollars less than the non-integrated cost in 1996. This difference increases to about sixty million dollars in 2010.

YEAR	COST/MONTH	MMs	COST/MONTH/MM
Non-Integrated			
1989	$ 1,417,122.00	85,529	$ 16.57
1991	$ 2,446,474.00	661,302	$ 3.70
Integrated			
1996	$ 5,919,620.00	8,533,500	$ 0.69
2000	$ 16,137,000.00	34,857,562	$ 0.46
2010	$ 29,184,800.00	161,504,572	$ 0.18
Non-Integrated			
1996	$ 10,604,035.00	9,094,900	$ 1.17
2000	$ 20,207,500.00	37,104,024	$ 0.81
2010	$ 88,522,460.00	164,184,932	$ 0.54

EXHIBIT ES-25. Summary Of IRN Circuit Cost Projections

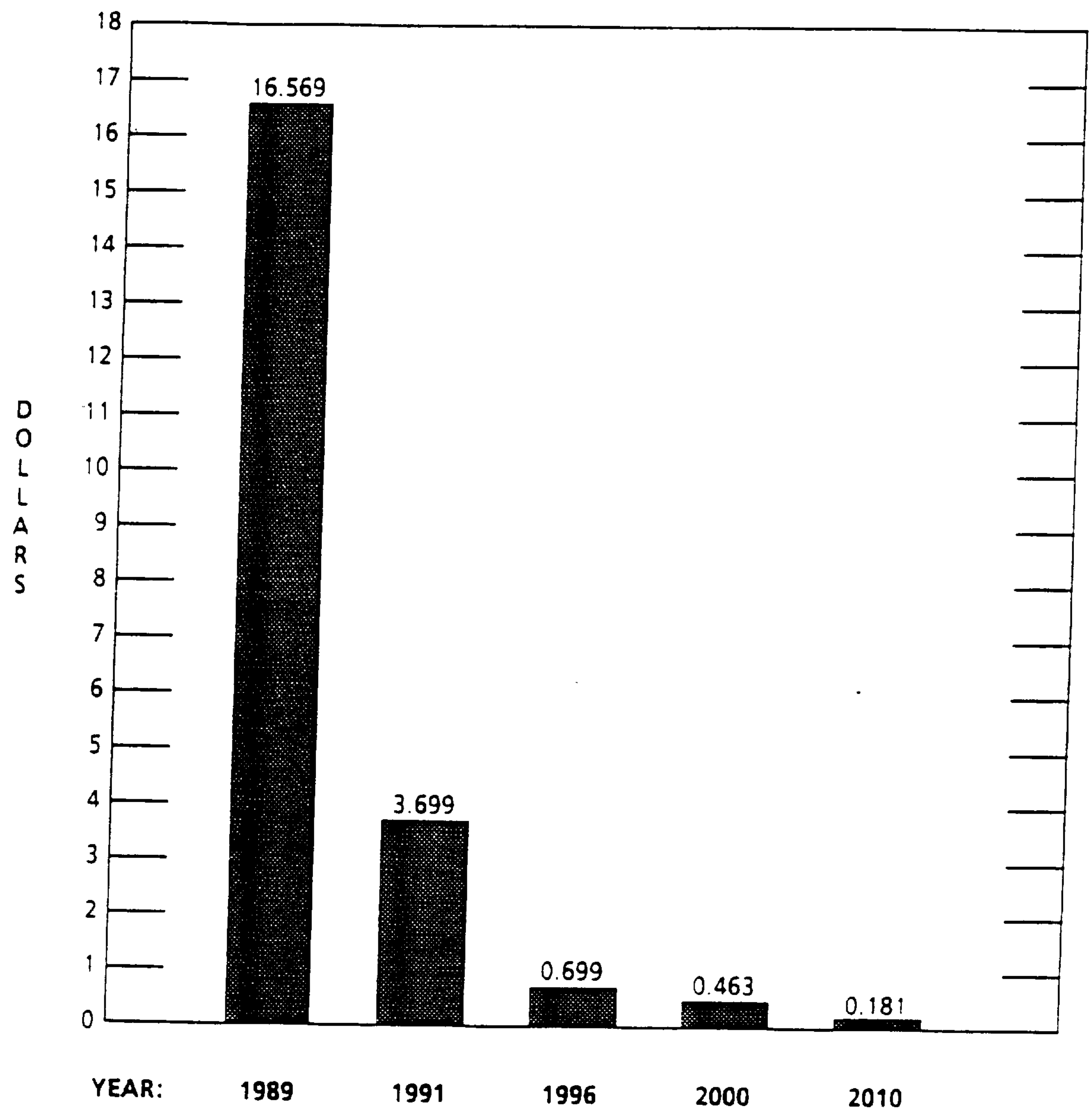

EXHIBIT ES-26. Projections Of Monthly Costs/MM

(Not integrated in 1989 & 1991; Integrated in 1996 and Beyond)

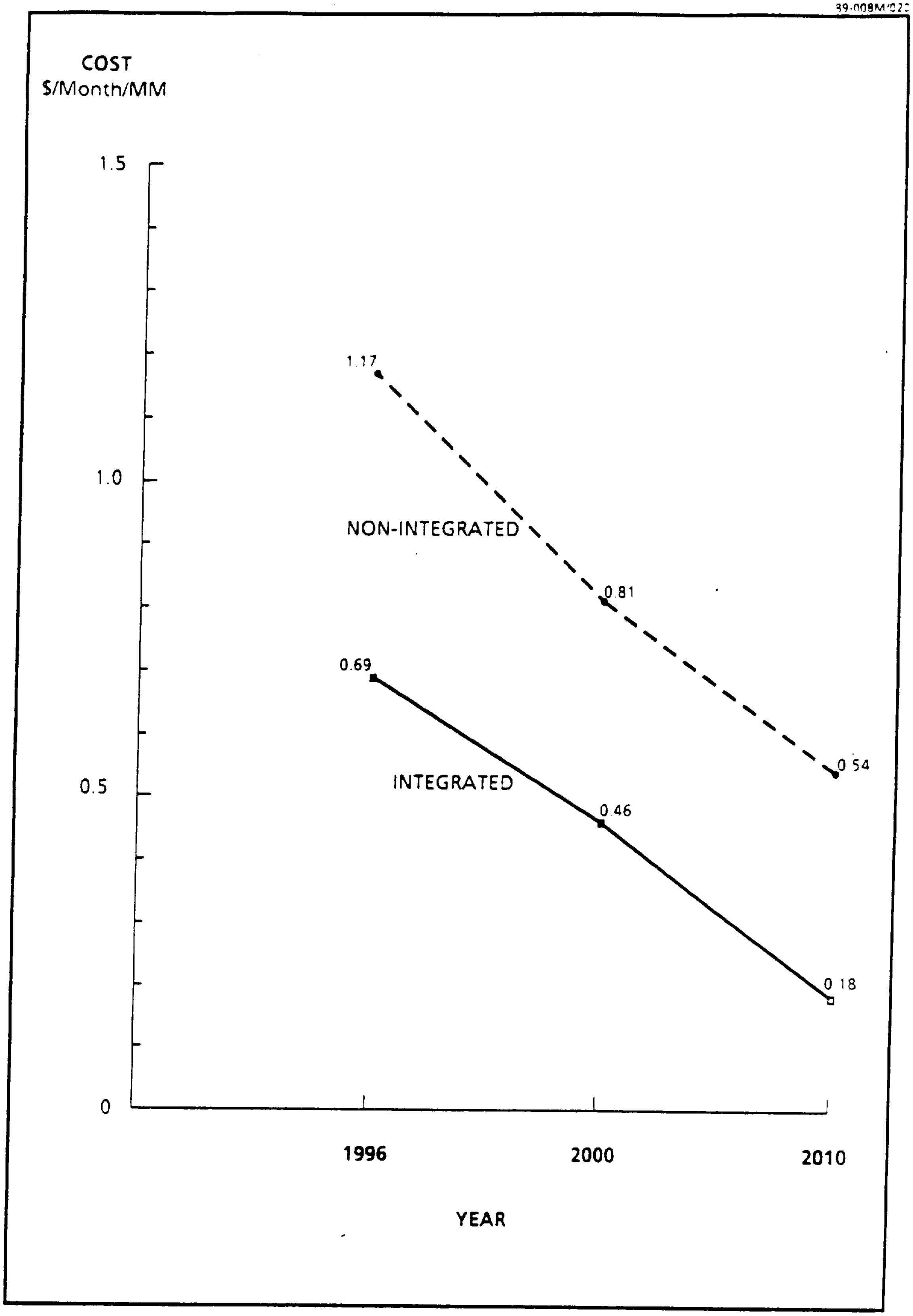

EXHIBIT ES-27. Comparison Of Monthly Cost/MM

Integrated Vs Non-Integrated IRN

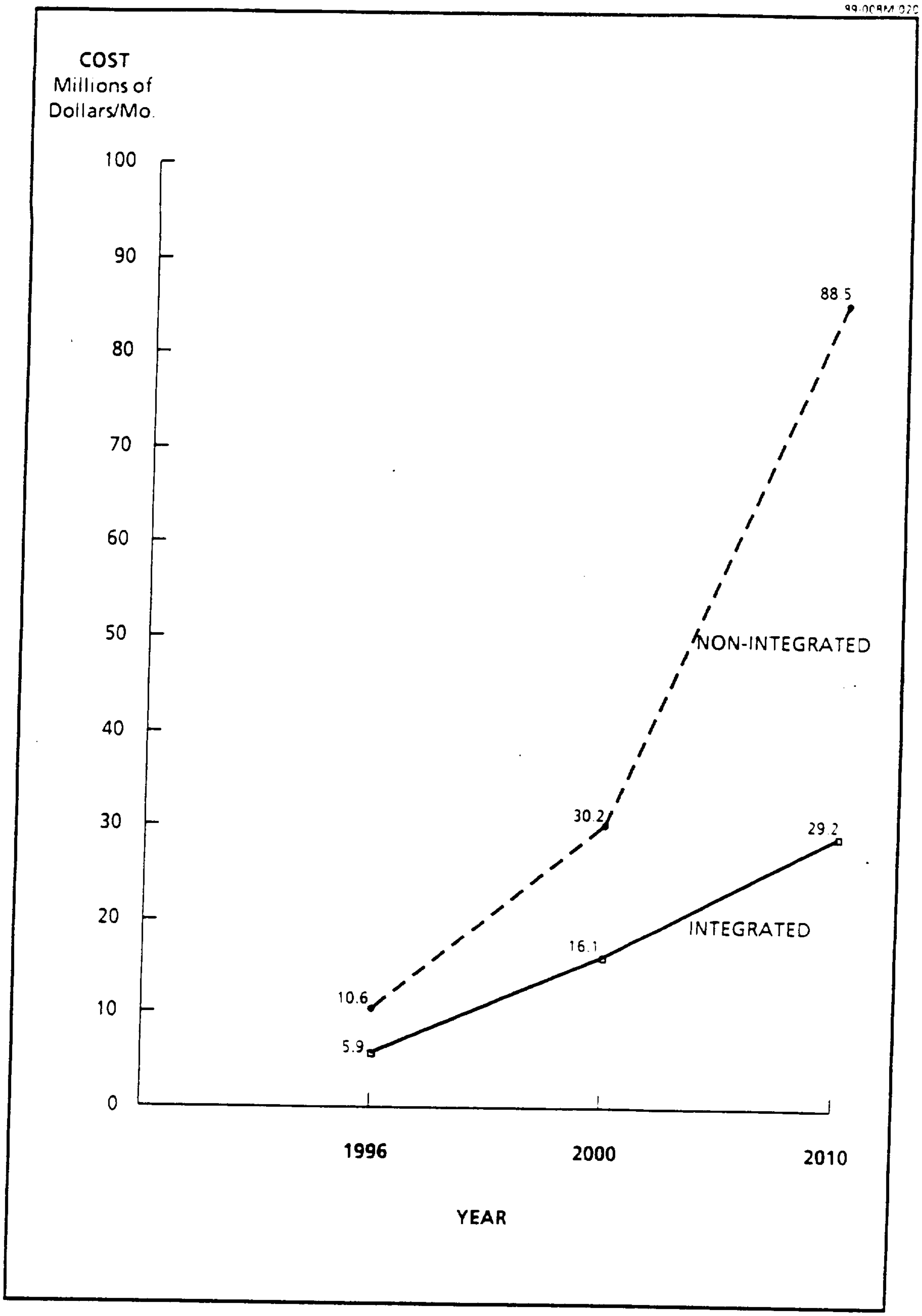

EXHIBIT ES-28. Comparison Of Monthly IRN Circuit Cost

Integrated Vs Non-Integrated IRN

APPENDIX A

LIST OF ABBREVIATIONS

LIST OF ABBREVIATIONS

All abbreviations are defined when they first appear in the text. Those abbreviations that are used more than once in the text are listed and defined here.

ABBREVIATION	MEANING
ARC	Ames Research Center
ARPANET	Advanced Research Projects Agency Network
BARRNET	Bay Area (No. California) Regional Research Network
BBN	Bolt, Baranek and Newman
BITNET	Before Its Time Network
CAN	Campus Area Network
CICNET	Committee on Institutional Cooperation Network
CRA	Computer Research Applications
CRN	Computer Research Network
CSNET	Computer + Science Network
CTSS	Cray Time Sharing System
DARPA	Defense Advanced Research Projects Agency
DCA	Defense Communications Agency
DDN	Defense Data Network
DDN/PMO	DDN Program Management Office
DECNET	Digital Equipment Corporation (DEC) Communications Software Products
DOD	Department of Defense
DOE	Department of Energy
DRI	Defense Research Internet
EDUCOM	Non-profit consortium of institutions of higher education.
ER	Energy Research
ESNET	Energy Science Network
FCCSET	Federal Coordinating Council for Science, Engineering & Technology
FRICC	Federal Research Internet Coordinating Committee
GSFC	Goddard Space Flight Center

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
HEP	High Energy Physics
HEPNET	High Energy Physics Network
IN	International Network
IPTO	Information Processing Techniques Office
IRN	Integrated Research Network
ISO	International Standards Organization
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JVNC	John von Neumann Center
JVNCNET	John von Neumann National Supercomputer Center Network
KSP	Kennedy Space Center
LAN	Local Area Network
LEP3NET	LEP = an accelerator at Cern, 3 = experiment number
MAN	Metropolitan Area Network
MERIT	Membership consortium of Michigan universities
MFE	Magnetic Fusion Energy
MFENET	Magnetic Fusion Energy Network
MIDNET	Membership consoritum of midwestern universities
MM	Megabits Per Second Mile - The movement of one megabit per second one mile
MRNET	Minnesota Regional Network
MSFC	Marshall Space Flight Center
NASA	National Aeronautics & Space Administration
NASCOM	NASA's communication network (Goddard)
NASNET	Numerical Aerodynamics Simulation Network
NCAR	National Center for Atmospheric Research
NCSA	National Center for Supercomputer Applications
NCSANET	National Center for Supercomputing Applications Network
NIC	Network Information Center
NIH	National Institutes of Health
NIST	National Institute of Standards & Technology
NJE/NJI	Network Job Entry/Network Job Interface

LIST OF ABBREVIATIONS

(CONTINUED)

ABBREVIATION	MEANING
NMFECC	National Magnetic Fusion Energy Computer Center
NN	National Network
NNT	National Network Test Bed
NOAA	National Oceanic & Atmospheric Administration
NOC	Network Operations Center
NORTHWESTNET	Membership consortium in Northwest
NRC	National Research Council
NRI	National Research Initiatives
NRN	National Research Network
NRNRC	National Research Network Review Committee
NSECC	NASA Space & Earth Sciences Computing Center
NSF	National Science Foundation
NSFNET	National Science Foundation Network
NSI	NASA Science Internet
NSN	NASA Science Network
NSP	Non Standard Protocols
NTIA	National Telecommunications & Information Administration
NTTF	Networking & Telecommunications Task Force (EDUCOM)
NYSERNET	New York State Education and Research Network (Cornell)
OARNET	Ohio Academic Resources Network
OASC	Office of Advance Scientific Computing (NSF)
OPMODEL	DOE Operational Model Network
OSI	Open Systems Interconnect
OSSA	Office of Space Science & Applications
OSTP	Office of Science & Technology Policy (White House)
PSCAA	Pittsburgh Supercomputer Center Academic Affiliates
PSCN	Program Support Communications Network (MSFC)
PSCNET	Pittsburgh Supercomputing Center Network
PSN	Public Switched Network
RIB	Research Interagency Backbone
RIG	Research Interagency Gateways
RN	Regional Network

LIST OF ABBREVIATIONS
(CONTINUED)

ABBREVIATION	MEANING
SCD	Scientific Computing Disvision (NCAR)
SCS	Scientific Computing Staff (DOE/Office Of Energy Research)
SDCS	San Diego Supercomputer Center
SDSCNET	San Diego Supercomputer Center Network
SESQUINET	Texas Sesquicentennial Network
SN	State Network
SPAN	Space Physics Analysis Network
SURANET	Southeastern Universities Research Association Network
TCP/IP	Transmission Control Protocol/Internet Protocol
THENET	Texas Higher Education Network
USAN	University Satellite Network
WESTNET	Network of five western states: AZ, CO, NM, UT, and WY
WN	Worldwide Network

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The current and future telecommunications overview of capacity and connectivity requirements of the United States domestic research and development (R & D) community are identified. Starting with 1989 as the base year, projection are made for the years 1996 2000, and 2010. It is known, that it is much more cost effective to implement researchers requirements as an integrated network rather than a piece meal basis, as is the case today.

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